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APTI Course 435, Atmospheric Sampling
Instructor's Guide

Northrop Services, Inc.
Research Triangle Park, NC

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

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16. ABSTRACT

The Instructor's Guide for Air Pollution Training Institute Course 435 "Atmospheric Sampling" contains guidelines for conducting a four and one-half day course in ambient sampling. The Guide contains lesson plans, laboratory instructions, exams, and solutions to problem sets. The lesson plans include keys to APTI audio visual materials and suggested instructional techniques. These materials are intended for use in conjunction with Student Manual EPA 450/2-80-004 and Student Laboratory and Exercise Manual EPA 450/2-80-005.

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APTI
Course 435
Atmospheric Sampling

Instructor's Guide

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Notice

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Availability of Copies of This Document

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Schools or governmental air pollution control agencies establishing training programs may receive single copies of this document, free of charge, from the Air Pollution Training Institute, USEPA, MD-20, Research Triangle Park, NC 27711. Others may obtain copies, for a fee, from the National Technical Information Service, 5825 Port Royal Road, Springfield, VA 22161.

AIR POLLUTION TRAINING INSTITUTE
MANPOWER AND TECHNICAL INFORMATION BRANCH
CONTROL PROGRAMS DEVELOPMENT DIVISION
OFFICE OF AIR QUALITY PLANNING AND STANDARDS

The Air Pollution Training Institute (1) conducts training for personnel working on the development and improvement of state, and local governmental, and EPA air pollution control programs, as well as for personnel in industry and academic institutions; (2) provides consultation and other training assistance to governmental agencies, educational institutions, industrial organizations, and others engaged in air pollution training activities; and (3) promotes the development and improvement of air pollution training programs in educational institutions and state, regional, and local governmental air pollution control agencies. Much of the program is now conducted by an on-site contractor, Northrop Services, Inc.

One of the principal mechanisms utilized to meet the Institute's goals is the intensive short term technical training course. A full-time professional staff is responsible for the design, development, and presentation of these courses. In addition the services of scientists, engineers, and specialists from other EPA programs governmental agencies, industries, and universities are used to augment and reinforce the Institute staff in the development and presentation of technical material.

Individual course objectives and desired learning outcomes are delineated to meet specific program needs through training. Subject matter areas covered include air pollution source studies, atmospheric dispersion, and air quality management. These courses are presented in the Institute's resident classrooms and laboratories and at various field locations.

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INTRODUCTORY MATERIAL

COURSE #435 -- ATMOSPHERIC SAMPLING

This Instructor's Guide is to provide you as Course Moderator with assistance in the preparation and presentation of Course #435 -- Atmospheric Sampling. It will provide you with guidelines, instructions and some general information that should facilitate your efforts in staging this course.

I. Course Description and Prerequisites

This course is an introduction to the measurement of gaseous flow and to general techniques employed in atmospheric sampling. Methods of calibration and use of flow rate measuring instruments are discussed in lectures and investigated in the laboratories. General techniques for sampling of the atmosphere as well as reference methods for sampling and analyzing criteria pollutants are discussed in the lectures. Certain specific characteristics of general sampling techniques (i.e., effects of storage time on bag samples of pollutants, etc.) are investigated in the laboratories. A scientific calculator is helpful for class and laboratory work. Student backgrounds including general science and basic math skills are essential.

II. Background, Origin, and Philosophy

The Environmental Protection Agency Air Pollution Training Institute (APTI) provides courses in air pollution control technology, ambient and source monitoring, and air quality management. In July, 1976, Northrop Services, Inc. was contracted to both present Training Institute Courses and to provide support and technical services for the Institute as a whole. Atmospheric sampling and other laboratory courses of particular importance to governmental and industrial personnel concerned with air pollution problems received early efforts of instructional development to design the best possible training experiences for the students. This required thorough examination of both the materials for instruction and an examination of the characteristics of the student audience. From such studies, the courses have been revised and developed to provide training that enables every student to achieve the specific course objectives.

The demographic characterization of students attending atmospheric sampling classes has shown the following:

Figure 1

Employer	Course 435
Federal EPA	3%
Other Federal	8%
State Government	43%
Local Government	18%
Industry	21%
Consultant	3%
Other	4%

Figure 2

Occupation	Course 435
Administrator	2%
Chemist	17%
Engineer	18%
Ind. Hygienist	3%
Phys. Scientist	8%
Sanitarian	8%
Technician	40%
Other	3%

Figure 3

Educational Background	Course 435
High School	32%
Bachelor	50%
Master	16%
PhD	2%

Figure 4

Years Experience	Course 435
0 - 1 years	42%
2 - 4	37%
5 - 7	11%
8 - 10	3%
> 10	7%

Student intellectual characteristics were determined in the initial contract year through standardized ability testing given to a total of 186 individuals in 10 different courses offered by the Institute. The Course #435 sample produced the following percentile rank scores:

Figure 5

	Percentile Rank
Verbal ability	74%
Numerical	56%
Spatial	38%
Reasoning	48%
Memory	41%

III. Educational Approach

The characterization studies mentioned above have indicated that for APTI atmospheric sampling courses, the course content and instructional methods should be explicit rather than implicit. Although formal educational level tends to be generally high, the ability testing has indicated the need for the course content to be presented in a careful and logical and consistent order with the underlying principles and relationships of given concepts being taught directly. At critical junctures where students are required to visualize a concept, infer a relationship, or visualize an added dimension, instruction is mediated with the use of:

- Graphic illustrations, usually in the form of 35 mm slides,
- Lecture demonstrations,
- In-class problem-solving,
- Hands-on laboratory experience
- Constant repetition and review of fundamental concepts

Course 435 is intended for personnel involved in sampling for atmospheric pollutants, as well as those responsible for purchase, calibration, and set up of atmospheric sampling equipment.

A typical person engaging in atmospheric sampling normally stays in this type of work for 2 or 3 years before moving on to another position. This creates a continual need to train new people entering this field of work. Students attending #435 have ranged from high school graduates to Ph.D.'s involved in research work. The average student (see Figures 2 and 3) has a bachelor's degree and is employed as a technician, chemist, or engineer. In this course, the students come from industry and governmental agencies (this provides a forum for interesting discussions during the course presentations). Most of the students are also just entering the field of air pollution, having less than one year of experience. The approach taken in instructing Course #435 is to direct the level of instruction towards the technical person with two to four years of college, newly entering the field of air pollution. This approach has succeeded, with most students gaining the knowledge they desired through the course experience.

The variety of activities that the student experiences in Course #435 aides in the assimilation of a great deal of knowledge. The first day of the course is a very intensive and often stressful series of lecture sessions. After this, laboratory experiences provide a more balanced schedule and often are a reinforcement of the concepts developed in Monday's lectures. The lectures for Tuesday through Thursday constitute more general background to leave the students with a broader understanding of atmospheric sampling. Friday morning discussion sessions are designed to provide the student with feedback on the lab experiences, and to answer student questions for individual problem areas.

Every effort is made to answer any question asked by a student even at the expense of some of the more advanced members of the class. In fact, it has occurred that the simpler questions lead into details that the class as a whole finds valuable. At the opposite end, the more complex questions give the beginning atmospheric sampler an opportunity to realize the complexities that can arise in performing atmospheric sampling.

IV. Instructions for Preparation and Presentation of Course

A. Responsibilities of Course Moderator

This course generally requires 4½ days for a complete presentation. It can also be expected that anywhere from 10 to 16 hours of additional preparation will be required by the individual designated Course Moderator. Preparation and continuity are the principle responsibilities of the Course Moderator who will coordinate all on-site activities both before and during the course presentation. The actual tasks that are considered the direct responsibility of the Course Moderator are:

1. Scheduling the course presentation.
2. Recruiting (hiring) and briefing instructors.
3. Preparation of classroom and teaching facilities.
4. Preparation of and distribution of course materials.
5. Presentation of introduction and other appropriate lectures.
6. Maintaining continuity throughout the course.

B. Scheduling

The course itself is designed around a format using 16 lectures and 3 laboratory sessions, all of which are designed to fit into a 4½ day time frame of morning and afternoon sessions. All three laboratory exercises are usually taught simultaneously with the students divided into three groups, A, B, and C. Because the course contains a concentrated level of involvement with rather technical material, it is recommended that no more than eight (8) hours of class instruction be presented in one day.

The course materials contain segments, each listed below with its recommended time and schedule placement.

Typical Sequence	Lesson Title	Expected Time Required
Day #1		
Lesson #1	Registration and Course Information	30 mins.
Lesson #2	Introduction to Atmospheric Sampling	1 hr. 15 mins.
Lesson #3	Gas measuring devices and their calibration — I and II	2 hrs.
Lesson #4	High Volume Method	1 hr.
Lesson #5	Generation of Test Atmospheres	1 hr. 15 mins.
Lesson #6	Air Movers	30 mins.

Typical Sequence	Lesson Title	Expected Time Required
Day #2		
Lesson #7	Problem Session I	45 mins.
Lesson #8	Principles of Gaseous Sampling	45 mins.
Lesson #9	Principles of Particulate Sampling	1 hr. 15 mins.
Lesson #10	Laboratory Briefing and Safety Considerations	30 mins.
Laboratory Session I	Lab 1 - Group A Lab 2 — Group B Lab 3 — Group C	4 hrs.
Day #3		
Lesson #11	Problem Session II	45 mins.
Lesson #12	Ambient Reference Methods for Gases — I and II	2 hrs.
Laboratory Session II	Lab 1 — Group B Lab 2 — Group C Lab 3 — Group A	4 hrs.
Day #4		
Laboratory Session III	Lab 1 — Group C Lab 2 — Group A Lab 3 — Group B	4 hrs.
Lesson #13	Surveillance Networks	45 mins.
Lesson #14	Site Selection	45 mins.
Lesson #15	Assuring High Quality Data	30 mins.
Lesson #16	Presentation of Laboratory Data	1 hr.

C. Instructors

The four most important criteria in the selection of faculty for this course are:

1. A knowledge of the current methods and procedures used in atmospheric sampling.
2. Recent practical experience with a facility providing sampling.
3. Experience (and ability) to instruct adults using traditional and non-traditional methods, materials, and techniques.
4. A positive attitude toward air quality management.

Before instructors are actually involved with instruction in the classroom the course moderator should conduct thorough briefing and preparation sessions in which an overview of the entire course presentation is given. Specific discussion of course and lesson objectives should result in an assurance that the instructors are well prepared and familiar with the materials, procedures, and techniques that they will be using.

The course moderator should stress the difference in the role that the instructor plays as compared to traditional university instruction situations. All instructors should fully understand the function of the course and lesson objectives and the relationship of each objective to their particular materials and to the pre- and post-testing.

It may be particularly helpful to the instructors if they are able to sit in on early sessions of the course presentation, so that they get a feel for the way the students are oriented to the material and be able to incorporate the strengths and background experiences of the students into the various instructional sessions.

Preparation must be stressed to all prospective instructors. Thorough familiarization with all the prepared materials is essential for even "expert" instructors. Laboratory sessions require additional preparation and should include a complete run-through to check out the methods and equipment before ever presenting them to the students. Remember that Murphy's law will always hold in a student laboratory exercise: "What ever can go wrong, will!"

D. Physical Setting

1. Classroom — a classroom of approximately 1200-1500 square feet is needed to accommodate 28-30 people (24 students, 3 instructors, 1 evaluator); all students should have desks or tables--others need chairs only
   - 35 mm slide projector
   - overhead projector
   - screen at least 6 feet by 6 feet
   - chalk board, erasers and chalk

2. Lab Facilities — should ideally have 3 separate rooms (can go with 2 rooms or one large room)
   - total of 10 people in each lab at one time

Lab 1: Hi Vol Lab	25 feet of standard lab bench top space, 7 to 10 electrical outlets, No less than two 20 amp circuits, extremely noisy lab — ideally should have its own room.
Lab 2: Flow Lab	30 feet of standard lab bench top space, 6 to 10 electrical outlets, best to have two 20 amp circuits, but not necessary, tap water supply is nice.
Lab 3: Test Atm.	25 feet of standard lab bench top space, 6 to 8 electrical outlets (only one 20 amp circuit necessary). Lab exhaust hood is best (can possibly do without), vacuum source (∿20-25 inches of mercury).

Total of 80 feet of standard lab bench top space.

More complete and specific laboratory instructions and equipment requirements are found in the final section of this guide.

E. Course Materials

In addition to the course lecture and lesson outlines and the audio-visual materials, this package contains the following material for distribution to the students:

1. APTI Training Manual: "Atmospheric Sampling"
2. Student Laboratory and Exercise Manual
3. Pre-test
4. Post-test
5. Daily quizzes I, II and III
6. Course Goal and Objectives
7. List of Designated Reference and Equivalent Methods*(this publication is updated frequently, the most recent version will be supplied)
8. "Optimum Site Exposure Criteria for SO_2 Monitoring" EPA-450/3-77-013 p. 31

F. Audio-Visual Materials

The visuals package accompanying these materials includes 474 35mm slides. The specific lessons are as follows:

Lesson 1	No slides
Lesson 2	38 slides
Lesson 3	67 slides
Lesson 4	61 slides
Lesson 5	34 slides
Lesson 6	17 slides
Lesson 7	No slides
Lesson 8	34 slides
Lesson 9	53 slides
Lesson 10	No slides
Lesson 11	No slides
Lesson 12	62 slides
Lesson 13	32 slides
Lesson 14	55 slides
Lesson 15	21 slides

These slides are either supplied as a part of the Instructional Resource package or are available for reproduction through the Air Pollution Training Institute.

G. Laboratory Materials and Equipment

The following list indicates the equipment and materials required for successful presentations of the lab sessions using the procedures contained in the Course 435 Laboratory Manual.

*Copies can be obtained from:
Office of Research and Development
EMSL (Environmental Monitoring Systems Lab)
US EPA-MD 77
Environmental Research Center
Research Triangle Park, NC 27711

EQUIPMENT LIST - LAB #435 ATMOSPHERIC SAMPLING

LAB 1 - CALIBRATION OF A HIGH VOLUME SAMPLER

1. Portable "in the field" calibration kit (optional)
2. 2 - Pressure transducers (Dixon meters) and Hi-vol blowers.
3. 2 - Visifloat and Hi-Vol blowers (used with rootsmeters)
4. 2 - Rootsmeters with stands
5. 4 - Water manometers - capable of measuring 16 inches or more
6. 2 - Mercury manometers - capable of measuring 160 mm or more
7. 4 - Ring stands and 10 - 3 prong holder clamps
8. 2 - Sierra or other make constant flow controller units
9. (Optional calibrator to correspond to constant flow unit)
10. One cartridge "type" filter holder (optional)
11. 2 - Orifice units (calibrator with load plates)
12. 4 - Electrical outlet - multiplugs - (extension cords ok)
13. 2 - Reference flow devices (Ref) (Dexco, Inc.)
14. Tubing - thin walled - Tygon.
15. Miscellaneous - (A) rubber gaskets
    (B) one box of clean filters (glass fiber)
    (C) oil - (rootsmeter grade oil)
    (D) Mercury
    (E) Distilled water with added coloring - ten drops/liter H_2O, e.g. fluorescein green dye

LAB 2 - FLOW MEASURING INSTRUMENTATION

(For two identical set-ups of each)

1. 2 - Mass flowmeters (0 - 3 liter range)
2. 2 - Displacement bottles (10 liter capacity)
3. 2 - Two liter class "A" volumetric flasks
4. 2 - Wet test meters (1 liter/rev)
5. 2 - Stopwatches
6. 2 - Vacuum pumps (capable of pulling 25" Hg vacuum)
7. 4 - Smog bubblers
8. 8 - Gas metering valves
9. 6 - Vacuum gages (0-30 "Hg vacuum range)
10. 4 - 500 ml Erlenmeyer flasks (plastic)
11. 2 - Particulate filters and holders (Teflon filters)
12. 2 - Moving soap bubble meters (graduated 0-500 ml)
13. 500 ml soap bubble solution
14. 2 - 250 ml beakers

LAB 2 - FLOW MEASURING INSTRUMENTATION (cont.)

15. 10 - Metal squeeze clamps for glass sockets
16. 4 - One-holed stoppers (rubber)
17. 2 - 2-holed stoppers (rubber)
18. 2 - 500 ml washbottles
19. 10 - ring stands
20. 4 - Mounting rods (horizontal)
21. 28 - 3-prong clamps
22. 2 - rotameters (glass) (0-3ℓ range)
23. 2 - 23 gauge hypodermic needles
24. 36 - clamp holders with 45° angle thumbscrews
25. 40' - 50' of vacuum tubing (rubber)
26. 6' - thin walled tubing (rubber)

LAB 3 - STANDARD TEST ATMOSPHERES

EQUIPMENT REQUIRED*

1. Continuous SO_2 Analyzer - (e.g. Teco Model 43)
2. Continuous NO_x-NO_2-NO Analyzer (e.g. Bendix 8102)
3. Portable Dilution system (e.g. Bendix Model 8861D)
4. Portable permeation System (e.g. Bendix Model)
5. Misc. (a) hardware - Swagelok fittings - clamps
    (b) tubing - e.g. Teflon and/or glass
    (c) mixing bulbs (glass) and/or glass manifold
    (d) support gases needed (1) Zero air
        (2) NO bottled gas. (50 ppm)
    (e) permeation tube 1 μg/min SO_2 @ calibrator/ permeation oven temperature

*May substitute other equipment so long as the principles put forth in the lab write-up are demonstrated i.e., permeation/dilution system utilized to calibrate monitor and gases and their dilution as an alternate calibration method.

H. Lesson Plan Use

Each lesson plan module is designed to serve as:

A. Source of lesson objectives
B. Content guide for instructor
C. Lecture outline
D. Directions for use of visual aids
E. Guidelines for approach to the lesson.

Generally the lesson plans are organized as straight outlines with additional instructions and keys to the visuals found on the right hand border of the page. On occasion it was felt that the instructor might need more specific information and a more narrative format is used for the subject matter to be adequately covered.

Each lecture plan outline is carefully timed. Instructors should give attention to observing time schedules and "pace" of the lessons to be given.

Instructors must be familiar with the visual aids and handout materials before attempting to present any lesson.

The visuals are keyed using number references that are also found on the slide. The number identifies the lecture and sequence of the slide. Thus, L2-16 identifies a slide in lecture 2 that comes before L2-17 and after L2-15. Also, each slide is provided with a "thumb spot" that should be in the upper right hand corner of the frame (under your thumb) as the slide is loaded into a carousel. This should prevent slides from being loaded backwards or upside-down.

Instructors may wish to vary slightly from the format or content for a given lesson but should be cautioned that the schedules and lesson objectives must be maintained. Variations should be in the direction of greater student participation. Instructors should remember that the exams reflect the lesson objectives as presented through these lesson outlines.

I. Grading Philosophy

The guidelines for grading student's performance in "Atmospheric Sampling" and granting Continuing Education Units (CEU's) are as follows:

The student must:

- attend a minimum of 95% of all scheduled class and laboratory sessions;
- complete and hand in copies of all laboratory data derived in the laboratories; and
- achieve an average course grade of 70% or better derived as follows:
    1) 25% from daily quizzes
    2) 45% from final examination
    3) 20% from laboratory reports
    4) 10% from homework completion

J. Other Logistics

Since the Course Moderator will need to consider a great variety of logistic and instructional concerns, the following checklist is provided to serve as a guide to meeting these responsibilities.

The course developers have tried to provide you with as much information and materials as possible to enable you to present a unique and exciting education venture.

GOOD LUCK.

CHECKLIST
of Activities
For Presenting the Course

A. Pre-Course Responsibilities:

______ 1. Reserve and confirm classroom(s) and laboratories, including size, "set-up," location and costs (if any).

______ 2. Contact and confirm all faculty (speakers) for the course(s), including their A-V requirements. Send material (i.e., slides and instructor's manual) to them. One or more pre-course instructor's meetings are advisable.

______ 3. Reserve hotel accommodations for faculty.

______ 4. Arrange for and confirm food service needs (i.e., meals, coffee breaks, water, etc).

______ 5. Prepare and reproduce final ("revise" if appropriate) copy of the detailed program schedule.

______ 6. Reproduce final registration/attendance roster, including observers (if any).

______ 7. Prepare name badges and name "tents" for students and faculty.

______ 8. Indentify, order, and confirm all A-V equipment needs.

______ 9. Prepare two or three 12 in. x 15 in. signs on posterboard for posting at meeting area.

______ 10. Arrange for and confirm any special administrative assistance needs on-site for course, including "local" address of welcome, etc.

______ 11. Obtain copies of EPA manuals, and pamphlets.

______ 12. Pack and ship box of supplies and materials one week prior to beginning of course (if appropriate).

______ 13. Arrange and confirm the availability of satisfactory laboratory equipment and facilities.

______ 14. Set up needed equipment in the laboratory setting and make sure all equipment and instruments are operating correctly.

______ 15. Have run through of lab exercise with instructors.

CHECKLIST (Cont.)

B. On-Site Course Responsibilities

_____ 1. Check on and determine final room arrangements (i.e., tables, chairs, lectern, water, cups, etc).

_____ 2. Set up A-V equipment required each day and brief operator (if supplied)

_____ 3. Post signs where needed.

_____ 4. Alert receptionist, phone operator(s) watchmen, etc., of name, location, and schedule of program.

_____ 5. Conduct a new speaker(s) (i.e., instructor) briefing session on a daily basis.

_____ 6. Verify and make final food services/coffee arrangements (where appropriate).

_____ 7. Identify and arrange for other physical needs as required (i.e., coat racks, ashtrays, etc).

_____ 8. Make a final check on arrival of guest speakers (instructors) for the day.

C. Post-Course Responsibilities

_____ 1. Request honorarium and expense statements from faculty; order and process checks.

_____ 2. Write thank-you letters and send checks to paid faculty.

_____ 3. Write thank-you letters to non-paid guest speakers and others who may have contributed to the success of the course.

_____ 4. Prepare evaluation on each course (including instructions, content, facilities, etc).

_____ 5. Make sure A-V equipment is returned.

_____ 6. Return unused materials to your office.

COURSE 435

ATMOSPHERIC SAMPLING

COURSE GOAL

The goal of this course is to introduce students to the concepts of atmospheric sampling for ambient levels of both gaseous and particulate pollutants. These concepts include selection of sampling sites, selection of sampling methods, and selection of calibration techniques.

COURSE OBJECTIVES

After completion of this course, the student will be able to:

a) calibrate (making all appropriate corrections for pressure drops, ambient temperature, atmospheric pressure, etc.) the following flow measuring devices:

   1) Wet test meters
   2) Rotameters
   3) Critical orifices
   4) Sub-critical orifices
   5) Mass flow meters
   6) Bubble flow meters

b) employ the devices listed in (a) to determine flow rates in various sampling trains and through various pieces of monitoring equipment covered during the course.

c) generate, analyze, and use controlled atmospheres of a gaseous pollutant to calibrate or examine certain parameters of gaseous sampling and analysis methods.

d) describe the operation of the various flow measuring devices and their associated calibration procedures. [see (a) above]

e) describe the analytical principles involved in gaseous sampling with emphasis on the criteria gaseous pollutants.

f) describe the various principles and instrumentation involved in particulate sampling.

g) describe the Federal Reference Method for particulates (TSP).

h) identify the manual procedure or measurement principle and associated calibration procedures of the reference methods presently specified for the analysis of ambient gaseous and particulate criteria pollutants.

i) identify the techniques used in siting monitoring stations.

j) identify the considerations involved in designing surveillance networks.

k) identify general characteristics of Quality Assurance.

l) interpret the effects of variables (i.e., flow rate, temperature, pressure, placement of rotameter in sampling trains, direction of flow through critical orifices, etc.) on the accuracy and precision of atmospheric sampling and analysis.

m) select the appropriate pieces of equipment to make up a sampling train (i.e., pumps, flow control and measuring devices, etc.) giving consideration to such parameters as pump capacity, interferences, flow rate required, etc.

LESSON OBJECTIVES

Lesson 1 - Registration and Course Information and Administering Pre-Test

Lesson 2 - "Introduction to Atmospheric Sampling"
At the completion of the lecture, the student will be able to:

- recall the general reasons for and types of sampling encountered in ambient surveillance.
- discuss the effects of temperature and pressure on the volume of an ideal gas.
- recognize the ideal gas law.
- Define the concept of molar volume and explain its use in atmospheric sampling.
- convert gas volumes (including the molar volume) to the conditions of standard temperature and pressure currently specified for EPA ambient reference methods.
- perform rudimentary sampling calculations such as determination of volume sampled, amount of pollutant collected, and conversion of $\mu g/m^3$ to ppm.

Lesson 3 - Gas Measuring Devices and their Calibration
After completion of this lecture, the student will be able to:

- define calibration
- distinguish between primary, intermediate, and secondary gas flow rate and volume standards
- distinguish among each of the following flow measurement instruments given operational and/or physical characteristics:
    a) wet test meters
    b) rotameters
    c) critical or limiting orifices
    d) sub-critical orifices
    e) moving bubble meters

- Identify the general characteristics of the following flow measurement instruments:
    - a) spirometers
    - b) displacement bottles
    - c) frictionless pistons
    - d) dry test meter
    - e) rootsmeters
    - f) pitot tubes
    - f) mass flow meters
- Apply appropriate factors to correct volume and flow rates for temperature and pressure
- Distinguish between volume, rate and velocity meters.

Lesson 4 - "High Volume Method"
The student will be able to:

- Briefly describe the components of a standard high volume sampler
- List the procedure for properly obtaining a high volume suspended particulate sample.
- Outline the procedure for calibrating a high volume calibration orifice using a rootsmeter.
- Recall and use the method for recalculating the orifice calibration curve when different temperature and pressure are involved.
- Describe and use the procedure for calibrating a high volume unit containing a visifloat or transducer.
- Discuss briefly the audit procedure for the high volume sampler.
- Calculate the total suspended particulate concentration for a high volume sample, given filter weights, flow rate, sampling time.
- Identify the common interferents (errors) associated with total suspended particulate measurement using the reference high volume method.

Lesson 5 - "Generation of Test Atmospheres"
After completion of this lecture, the student will be able to:

- identify the stability problems associated with low level cylinder gases--specifically, SO_2, NO_2, and CO.

- Given the appropriate data, perform all calculations necessary to determine the concentrations of gases produced by permeation systems and dilution systems
- Outline at least two methods for actually metering diluent gas into a static or dynamic system .
- Recognize and identify the adsorbents and apparatus necessary to produce zero air.
- Define NBS traceability in terms of Standard Reference Materials and non-NBS standards.
- Describe the construction and use of permeation tubes.

Lesson 6 - "Air Movers"
The student will be able to:

- List six considerations in selecting an air mover for a given sampling situation.
- Differentiate between positive displacement and centrifugal pumps.
- Describe the operation of the following air movers
  a. Piston pump
  b. Diaphragm pump
  c. Vane pumps
  d. Ejectors
  e. Liquid displacement

Lesson 7 - Problem Session I

Lesson 8 - "Principles of Gaseous Sampling"
The student will be able to:

- Distinguish between the principles of grab and integrated gas sampling.
- Identify the characteristics of adsorption, absorption, and freezeout sampling.
- List at least two common materials used as adsorbents.
- List the type of samples most commonly collected by adsorption and freezeout sampling.
- Describe at least one type of analytical procedure for quantifying gaseous pollutants collected by adsorption.
- List at least two potential problems common to adsorbent collection and analysis of gases.
- List at least two factors affecting collection efficiency of an absorber.
- Distinguish the difference between physical and chemical absorption.

Lesson 9 - "Principles of Particulate Sampling"
The student will be able to:

- Describe three principles of particulate collection devices: gravity, filtration, inertia, and recall examples of each.
- Identify at least two common errors in inertial collection of particulates.
- Describe the mechanism for size fractionation by inertial sampling.
- Define collection efficiency of an impaction device.
- List four properties of aerosols and four properties of collecting devices which affect the collection efficiency of impactors.
- Discuss how the following particulate samplers operate and what each is used for:

  a. Cascade Impactor
     (1) Andersen Impactor

  b. Cyclone Samplers

- Describe the rationale for size fractionation of ambient particulate matter.
- Define the differences between respirable and non-respirable particulate matter.
- Describe how the dichotomous sampler fractionates respirable and non-respirable particulate matter.
- Discuss some of the advantages and disadvantages of each of the three types of filter materials.

Lesson 10 - Laboratory Briefing and Safety

Lesson 11 - Problem Session II

Lesson 12 - "Ambient Reference Methods for Gases"
At the conclusion of this lecture, the student will be able to:

- Distinguish between a Reference Method or Measurement Principle and Calibration Procedure and an Equivalent Method for ambient air pollutants.
- List the gaseous ambient pollutants now specified as criteria pollutants.
- List the Reference Method or Measurement Principle and Calibration Procedure currently specified for each criteria pollutant.
- Describe the operating principles of each Reference Method.

Lesson 13 - "Elements of Surveillance Networks"
The student will be able to:

- Describe the need to specify the objectives of sampling tied to intended use of the data as the first step in designing the network.
- Cite the major sources of EPA guidance on monitor siting.
- Discuss the composition of SAMWG and the status of its recommendations
- Defend the need for a quality assurance program.
- Describe an ambient monitoring network including its major subsystems.

Lesson 14 - "Site Selection"
The student will be able to:

- Discuss the need to properly site pollutant monitors
- Locate the documents for guidance on siting pollutant monitors
- Outline the procedure used to site monitors as described in the guidance documents.
- Locate regulations associated with monitor siting
- Recognize factors involved in selecting proper siting of monitors.

Lesson 15 - "Quality Assurance Overview"
The student should be able to:

- Define Quality Assurance
- State three major reasons why a quality assurance program is important in sampling and analyzing atmospheric pollutants.
- Recognize that many different quality assurance elements are involved in the process of producing valid data, list several of those which are directly applicable to the individual who samples and analyzes atmospheric pollutants.
- Recognize that QA principles and specified QA methodologies are located in Vols. I & II of the Quality Assurance Handbook and 40 CFR Appendixes A & B.
- Recall that EPA conducts an Interlaboratory Performance Audit Survey and that participation (voluntary at present) will be required by 1983 in accordance with SLAMS provisions.

LABORATORY OBJECTIVES

"Lab 1: High Volume Sampler Calibration"

At the conclusion of this laboratory session the student will be able to:

- Calibrate an orifice calibration unit with a rootsmeter
- Calibrate, according to the Reference Method, a hi-vol equipped with a visi-float and a hi-vol sampler equipped with a recording pressure transducer.
- Perform a field audit on the flow calibration of a hi-vol using a ReF (reference flow) device.
- Perform a check on the constant flow performance of a constant flow hi-vol.

"Lab 2: Flow Calibration"

At the conclusion of this laboratory session, the student will be able to:

- Calibrate a wet-test meter using a water displacement technique.
- Calibrate a rotameter in a bubbler train using a mass flow meter. The student will be able to describe the effects that variation in ΔP will produce on flow measurements.
- Describe how various factors affect critical orifice flow. These factors include:
    a) determination of critical vacuum
    b) effects of upstream resistance
    c) effects of directional placement of a common orifice (hypodermic needle).
- Calibrate a mass flow meter.

"Lab 3: Controlled Test Atmospheres"

At the conclusion of this laboratory session, the student will be able to:

- Use bottled gas/dilution, dynamic test atmospheres to prepare a calibration curve of concentration vs. instrument response.
- Use permeation tube/dilution, dynamic test atmospheres to prepare a calibration curve of concentration vs. instrument response.
- Perform all calculations necessary for the utilization of the test atmospheres listed above.

SAMPLE AGENDA

Name and address of
agency conducting course

(Dates of course)

435--Atmospheric Sampling

Acknowledgement
of role of other
agencies, if any,
in conduct or
support of
presentation.

Course location

Name of course
director

DAY & TIME	SUBJECT	SPEAKER
MONDAY		
8:30	Registration and Course Information	
9:00	Pretest	
9:45	Introduction to Atmospheric Sampling	
:00	Gas Measuring Devices & Their Calibration I	
12:00	LUNCH	
12:45	Gas Measuring Devices & Their Calibration II	
1:45	High Volume Method	
2:45	BREAK	
3:00	Generation of Test Atmospheres	
4:15	Air Movers	
4:45	ADJOURN	

HOMEWORK:

1. **Problem Set 1 (Due Tuesday at 8:30 a.m.)**
2. **Read Appropriate Lab Procedures**

TUESDAY

8:30 Problem Session

If course is not conducted by EPA, but EPA/APTI materials are used, it would be appreciated that an acknowledgement appear here.

DAY & TIME	SUBJECT	SPEAKER
TUESDAY (Continued)		
9:15	Quiz I	
9:30	Principles of Gaseous Sampling	
10:15	BREAK	
10:25	Principles of Particulate Sampling	
11:40	LUNCH	
12:30	Laboratory Briefing & Safety	
1:00	Laboratory Session I Lab 1 - Group A Lab 2 - Group B Lab 3 - Group C	
5:00	ADJOURN	

HOMEWORK:

1. Problem set 2 (Due Wednesday at 8:30 a.m.)
2. Read Appropriate Lab Procedures
3. Complete Lab Report for Lab Session I (Due Wednesday at 1:00 p.m.)

DAY & TIME	SUBJECT	SPEAKER
WEDNESDAY		
8:30	Problem Session	
9:15	Quiz II	
9:30	Ambient Reference Methods for Gases I	
10:30	BREAK	
10:45	Ambient Reference Methods for Gases II	
11:45	LUNCH & Work Session	
1:00	Laboratory Session II Lab 1 - B Lab 2 - C Lab 3 - A	
5:00	ADJOURN	

HOMEWORK:

1. Complete lab report for Lab Session II (Due Thursday @ 8:30 a.m.)
2. Read Appropriate Lab Procedures
3. Review problem sets

DAY & TIME	SUBJECT	SPEAKER
THURSDAY		
8:30	Laboratory Session III Lab 1 - C Lab 2 - A Lab 3 - B	
12:30	LUNCH	
1:30	Work Session (Report for Lab Session III due at end of this session)	
2:00	Quiz III	
2:30	Surveillance Networks	
3:15	BREAK	
3:30	Site Selection	
4:15	Assuring High Quality Data	
4:45	ADJOURN	
HOMEWORK:	1. Study for Final Examination. Be sure to review pre-test, course and lecture objectives, daily quizzes, and lab materials. Be prepared to present lab data in class.	
FRIDAY		
8:30	Presentation of Laboratory Data (Graded lab reports returned to class)	
9:30	Review & Study	
10:30	Final Exam	
11:30	Review of Final Exam	
11:45	Course Evaluation	
12:00	ADJOURN	

COURSE 435

REQUIREMENTS FOR AWARD OF CERTIFICATE OF COURSE COMPLETION AND CONTINUING EDUCATION UNITS

Three (3) Continuing Education Units (CEU's) will be awarded along with certificate to those students who:

- attend a minimum of 95% of all scheduled class and laboratory sessions;
- complete and hand in copies of all laboratory data derived in the laboratories; and
- achieve an average course grade of 70% or better derived as follows:
    1) 25% from daily quizzes
    2) 45% from final examination
    3) 20% from laboratory reports
    4) 10% from homework completion

ALL PRE-TEST, POST-TESTS, AND QUIZZES IN THIS COURSE ARE INTENDED TO BE CLOSED-BOOK. STUDENTS ARE NOT ALLOWED TO USE ANY ADDITIONAL MATERIAL, OTHER THAN A SCIENTIFIC CALCULATOR. SUGGESTED TIME ALLOTMENTS FOR EACH ARE AS FOLLOWS:

PRE-TEST	45 MINUTES	QUIZ 1.	15 MINUTES
FINAL EXAM	60 MINUTES	QUIZ 2.	15 MINUTES
		QUIZ 3.	30 MINUTES

NAME ____________________________ DATE ________________________

COURSE 435

ATMOSPHERIC SAMPLING

PRE-TEST

This Pre-test is designed to measure your knowledge of atmospheric sampling as you enter Course 435. You will have approximately 45 minutes to complete the test. You are not expected to be able to answer all of the questions. This test is intended to be closed book and you are not to use any additional materials with the exception of a scientific calculator. The results of this test will not affect your final course grade.

Put all answers on the attached Answer Sheet.

1. Which of the following pollutants is the most stable at low level (e.g., 1-100 ppm) concentrations in compressed gas cylinders?

   a. carbon monoxide

   b. nitrogen dioxide

   c. sulfur dioxide

   d. ozone

2. An ideal gas occupies a volume of 250 ml at 20°C and 720 mm Hg. What volume does this gas occupy at 25°C and 760 mm Hg.?

   a. 241 ml
   b. 242 ml
   c. 257 ml
   d. 268 ml

3. The recorded permeation rate of an SO_2 permeation tube is 1.045 μg/minute at 25°C. If the total dilution flow is 3.7 liters/minute, what is the concentration of SO_2 in the diluted gas stream?

   a. 0.942 ppm
   b. 0.873 ppm
   c. 0.108 ppm
   d. 0.097 ppm

4. A particle moving in an air stream with approximately the same velocity as the air stream has more momentum than the volume of air that it displaces. The momentum possessed by a particle in a moving air stream will cause the particle to be deflected less than the air in the vicinity of the particle when the air stream undergoes a sudden change in direction. If the resulting deflection of the particle from the air trajectory around the obstacle is great enough, the particle will strike the obstacle. This is the principle on which ________________________ is based.

   a. isokinetic sampling
   b. predilection
   c. inertial sampling
   d. criticality

2/28/80

5. The collection efficiency of an impactor can be affected by the following aerosol properties:

   a. acerity, modulation, morphology
   b. operational density, redolence, aspect ratio
   c. particle velocity, particle density, particle size
   d. temperature, refractive index, mass median diameter

6. The collection efficiency of an impactor can be affected by the following collection device properties:

   a. jet size, jet shape, jet channel
   b. collection surface, distance between jet and collection surface, particle size
   c. collection surface, jet size
   d. homocedasticity, collection surface, jet size

7. In order to calibrate a hi-vol air sampler, one must:

   a. calibrate the orifice unit, then calibrate the visi-float (or recording transducer)
   b. calibrate the Rootsmeter against the visi-float
   c. calibrate the mercury manometer, then calibrate the orifice meter
   d. calculate the expected pressure drop across the forelope

8. **A hi-vol filter sample, after 24 hours of sampling at a constant rate of 40 cfm, weighed 3.222 gms. Initially the filter weighed 3.007 gms. What is the total mass of suspended particulate collected, in μg/M^3? (1 $ft.^3$=.02832 m^3)**

   a. 175
   b. 102
   c. 92
   d. 132

9. Two criteria considered in the selection of a particular air mover for a given sampling situation are:

   a. gear pumps and lobe pumps
   b. pollutant concentration and refractive index
   c. portability and required sampling rate
   d. particle size and cost

10. A linear relationship between suction pressure and pump capacity often characterizes a (1) ________________ while (2) ________________ are representative of pumps exhibiting a non-linear relationship.

   a. (1) radial flow pump; (2) centrifugal pumps
   b. (1) centrifugal pump; (2) radial flow pumps
   c. (1) centrifugal pump; (2) positive displacement pumps
   d. (1) positive displacement pump; (2) centrifugal pumps

11. Which best describes the reason for collecting trace organic vapors on an adsorbent?

   a. irreversibly binds the compound to the adsorbent
   b. removes the pollutant from the sample stream and concentrates the compound so that it can be detected by the analytical procedure.
   c. provides a surface for the absorption of the pollutant
   d. none of the above.

12. The two specified methods for the calibration of a nitrogen dioxide channel of a NO-NO_x-NO_2 analyzer are:

   a. Rapid gas phase titration of NO with excess ozone or the use of a NO_2 permeation tube.
   b. Rapid gas phase titration of NO with ethylene or the use of a NO_2 permeation tube.
   c. The use of cylinder NO_2 or the use of a NO_2 permeation system.
   d. None of the above

13. The reference measurement principle for the detection of ozone in ambient air is which of the following?

   a. the chemiluminescence reaction of ozone and nitric oxide
   b. UV photometry
   c. the chemiluminescence reaction of ozone and ethylene
   d. mass spectrometry

14. The retention of sulfur dioxide in potassium tetrachloromercurate solution is primarily an example of which of the following?

   a. chemical adsorption
   b. physical adsorption
   c. chemical absorption
   d. physical absorption

15. As the bubble size of a gas passing through an absorbing solution increases, the collection efficiency generally

   a. remains the same
   b. decreases
   c. increases slightly
   d. increases drastically

16. Given the following data on a tank of NO and its dilution system which are being used to calibrate a NO-NO_2-NO_x analyzer, what is the concentration of NO delivered to the instrument?

   Tank NO concentration: 97.3 ppm by volume
   NO flow rate: 10.4 ml/min
   Dilution Air Flow Rate: 4300 cc/min

   a. 0.496 ppm
   b. 0.176 ppm
   c. 0.230 ppm
   d. 0.973 ppm

17. What are the standard conditions of temperature and pressure which are specified by EPA for ambient air sampling?

a. 70°F and 29.92 in Hg.
b. 20°C and 760 mm Hg.
c. 25°C and 760 mm Hg.
d. 20°C and 76 cm Hg.

18. Removal of hydrocarbons from ambient air by activated charcoal is an example of:

a. desiccation
b. adsorption
c. absorption
d. solution

19. Which of the following represent major interferents in the detection of carbon monoxide in ambient air by non-dispersive infrared spectrometry?

a. O_3, NO_2 and H_2S

b. CO_2, water vapor, and certain hydrocarbons

c. NO and molecular oxygen

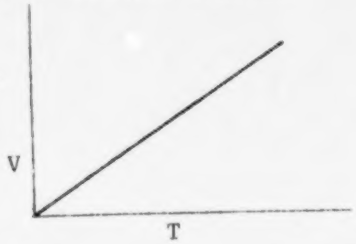
d. all of the above.

20. SAMWG (Standing Air Monitoring Work Group) was formed in October 1975 and its major findings include:

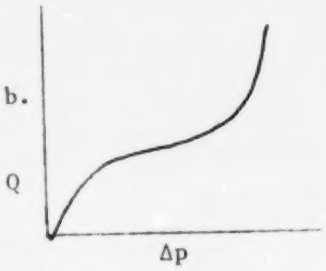
a. Data being produced was of unknown quality.
b. Lack of coordination of monitoring activities.
c. Location of monitors was not systematic
d. a and c
e. b and c
f. a, b, and c

21. Select which of the following graphs represents the calibration curve for a critical orifice.

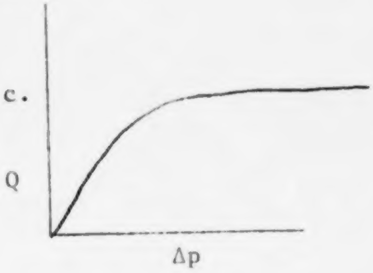
a.



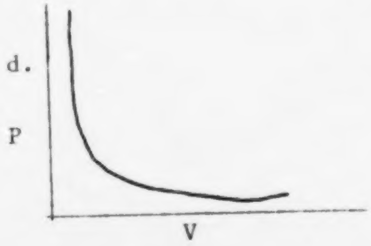
b.



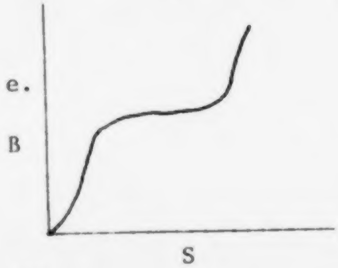
c.



d.



e.



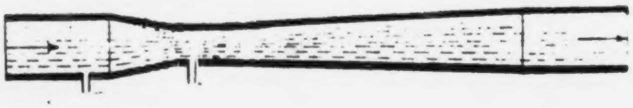
22. Match the following: (from choices 1-10)

a. ________spirometer

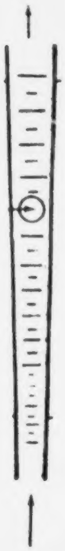
b. ________displacement bottle

c. ________Rootsmeter

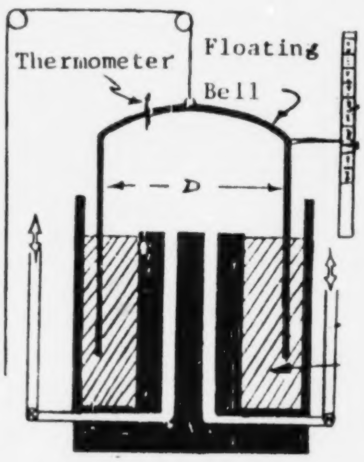
d. ________bubble meter



1

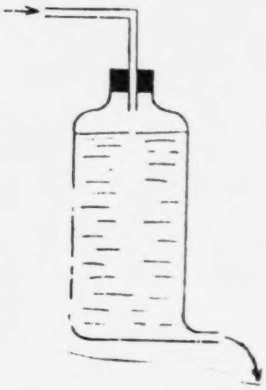


4



3

2



5) the interior contains two or more movable partitions, or diaphragms, attached to the case by a flexible material so that each partition may have a reciprocating motion.

6) "hot wire"

7) standard or "S" type

8) positive displacement meter utilizing mechanical linkages to indicate volume

9) graduated cylindrical glass tube up which a soap film moves

10) primary standard utilizing a mercury seal

23. Identify the following as: (P) primary calibration standards or (S) secondary calibration standards or (I) intermediate standards.

a. __________wet-test meter
b. __________rotameter
c. __________critical orifice
d. __________frictionless piston
e. __________spirometer

24. Match the following reference methods or principles:

a. ________CO
b. ________O_3
c. ________SO_2
d. ________NO_2

(1) pararosaniline
(2) t-butyl mercaptan
(3) NDIR
(4) chemiluminescence with ethylene
(5) flame ionization
(6) chemiluminescence with ozone

25. TRUE OR FALSE Grab sampling is illustrated by sampling with a midget impinger at a flow rate of 250 ml/min. for 30 minutes, while integrated sampling is illustrated by sampling with an evacuated container.

26. TRUE OR FALSE A bag containing 100 liters of 1.0 ppm NO_2 is an example of a static test atmosphere.

27. TRUE OR FALSE The regulations on the siting of ambient air quality monitors are contained in the appendixes of 40 CFR 58.

28. TRUE OR FALSE A mass flow meter has the advantage of being relatively insensitive to temperature and pressure and therefore does not require corrections for these parameters.

29. TRUE OR FALSE Quality assurance can be defined as "quality control for quality control".

30. TRUE OR FALSE Direction of flow through a hypodermic needle acting as a limiting orifice has no effect on its flow rate.

NAME________________________________ DATE________________________

COURSE 435

ATMOSPHERIC SAMPLING

PRE-TEST

Answer Sheet

1. a b c d
2. a b c d
3. a b c d
4. a b c d
5. a b c d
6. a b c d
7. a b c d
8. a b c d
9. a b c d
10. a b c d
11. a b c d
12. a b c d
13. a b c d
14. a b c d
15. a b c d
16. a b c d
17. a b c d
18. a b c d
19. a b c d
20. a b c d e f
21. a b c d e

22. a______
    b______
    c______
    d______

23. a______
    b______
    c______
    d______
    e______

24. a______
    b______
    c______
    d______

25. T F
26. T F
27. T F
28. T F
29. T F
30. T F

NAME Key DATE

COURSE 435

ATMOSPHERIC SAMPLING

PRE-TEST

This Pre-test is designed to measure your knowledge of atmospheric sampling as you enter Course 435. You will have approximately 45 minutes to complete the test. You are not expected to be able to answer all of the questions. This test is intended to be closed book and you are not to use any additional materials with the exception of a scientific calculator.

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   [✓ a.] carbon monoxide
   b. nitrogen dioxide
   c. sulfur dioxide
   d. ozone

2. An ideal gas occupies a volume of 250 ml at 20°C and 720 mm Hg. What volume does this gas occupy at 25°C and 760 mm Hg.?

   [✓ a.] 241 ml
   b. 242 ml
   c. 257 ml
   d. 268 ml

$$V_{(25°C, 760\,mmHg)} = 250\,\frac{720}{760}\,\frac{298}{293} = 240.9 \simeq 241\text{ ml}$$

3. The recorded permeation rate of an SO_2 permeation tube is 1.045 µg/minute at 25°C. If the total dilution flow is 3.7 liters/minute, what is the concentration of SO_2 in the diluted gas stream?

   a. 0.942 ppm
   b. 0.873 ppm
   [✓ c.] 0.108 ppm
   d. 0.097 ppm

$$\frac{(1.045\,\mu g/min)(24.46\,\mu l/\mu mole)}{(64\,\mu g/\mu mole\,SO_2)(3.7\,liters/min)} = .108\,\mu l/l = .108\text{ ppm}$$

4. A particle moving in an air stream with approximately the same velocity as the air stream has more momentum than the volume of air that it displaces. The momentum possessed by a particle in a moving air stream will cause the particle to be deflected less than the air in the vicinity of the particle when the air stream undergoes a sudden change in direction. If the resulting deflection of the particle from the air trajectory around the obstacle is great enough, the particle will strike the obstacle. This is the principle on which ________________ is based.

   a. isokinetic sampling
   b. predilection
   [✓ c.] inertial sampling
   d. criticality

5. The collection efficiency of an impactor can be affected by the following aerosol properties:

   a. acerity, modulation, morphology
   b. operational density, redolence, aspect ratio
   [✓ c.] particle velocity, particle density, particle size
   d. temperature, refractive index, mass median diameter

6. The collection efficiency of an impactor can be affected by the following collection device properties:

   a. jet size, jet shape, jet channel
   b. collection surface, distance between jet and collection surface, particle size
   [✓ c.] collection surface, jet size
   d. homocedasticity, collection surface, jet size

7. In order to calibrate a hi-vol air sampler, one must:

   [✓ a.] calibrate the orifice unit, then calibrate the visi-float (or recording transducer)
   b. calibrate the Rootsmeter against the visi-float
   c. calibrate the mercury manometer, then calibrate the orifice meter
   d. calculate the expected pressure drop across the forelope

8. A hi-vol filter sample, after 24 hours of sampling at a constant rate of 40 cfm, weighed 3.222 gms. Initially the filter weighed 3.007 gms. What is the total mass of suspended particulate collected, in μg/M^3? (1 ft.^{3} = .02832 m^3.)

   a. 175
   b. 102
   c. 92
   [✓ d.] 132

$$TSP = \frac{(3.222-3.007)_g\,(10^6\ \mu g/g)}{(40\ cfm)\left(\frac{.02832\ m^3}{ft.^3}\right)(1440\ min)} = 132\ \mu g/m^3$$

9. Two criteria considered in the selection of a particular air mover for a given sampling situation are:

   a. gear pumps and lobe pumps
   b. pollutant concentration and refractive index
   [✓ c.] portability and required sampling rate
   d. particle size and cost

10. A linear relationship between suction pressure and pump capacity often characterizes a (1) ____________ while (2) ____________ are representative of pumps exhibiting a non-linear relationship.

    a. (1) radial flow pump; (2) centrifugal pumps
    b. (1) centrifugal pump; (2) radial flow pumps
    c. (1) centrifugal pump; (2) positive displacement pumps
    [✓ d.] (1) positive displacement pump; (2) centrifugal pumps

11. Which best describes the reason for collecting trace organic vapors on an adsorbent?

a. irreversibly binds the compound to the adsorbent
[✓ b.] removes the pollutant from the sample stream and concentrates the compound so that it can be detected by the analytical procedure.
c. provides a surface for the absorption of the pollutant
d. none of the above.

12. The two specified methods for the calibration of a nitrogen dioxide channel of a NO-NO_x-NO_2 analyzer are:

[✓ a.] Rapid gas phase titration of NO with excess ozone or the use of a NO_2 permeation tube.
b. Rapid gas phase titration of NO with ethylene or the use of a NO_2 permeation tube.
c. The use of cylinder NO_2 or the use of a NO_2 permeation system.
d. None of the above

13. The reference measurement principle for the detection of ozone in ambient air is which of the following?

a. the chemiluminescence reaction of ozone and nitric oxide
b. UV photometry
[✓ c.] the chemiluminescence reaction of ozone and ethylene
d. mass spectrometry

14. The retention of sulfur dioxide in potassium tetrachloromercurate solution is primarily an example of which of the following?

a. chemical adsorption
b. physical adsorption
[✓ c.] chemical absorption
d. physical absorption

15. As the bubble size of a gas passing through an absorbing solution increases, the collection efficiency generally

a. remains the same
[✓ b.] decreases
c. increases slightly
d. increases drastically

16. Given the following data on a tank of NO and its dilution system which are being used to calibrate a NO-NO_2-NO_x analyzer, what is the concentration of NO delivered to the instrument?

Tank NO concentration: 97.3 ppm by volume
NO flow rate: 10.4 ml/min
Dilution Air Flow Rate: 4300 cc/min

$C_1Q_1 = C_2Q_2$

$(97.3 \text{ ppm})(10.4 \text{ ml/min}) = C_2 (4310.4 \text{ ml/min})$

$.235 \text{ ppm} = C_2$

a. 0.496 ppm
b. 0.176 ppm
[✓ c.] 0.230 ppm
d. 0.973 ppm

17. What are the standard conditions of temperature and pressure which are specified by EPA for ambient air sampling?

- a. 70°F and 29.92 in Hg.
- b. 20°C and 760 mm Hg.
- [✓ c.] 25°C and 760 mm Hg.
- d. 20°C and 76 cm Hg.

18. Removal of hydrocarbons from ambient air by activated charcoal is an example of:

- a. desiccation
- [✓ b.] adsorption
- c. absorption
- d. solution

19. Which of the following represent major interferents in the detection of carbon monoxide in ambient air by non-dispersive infrared spectrometry?

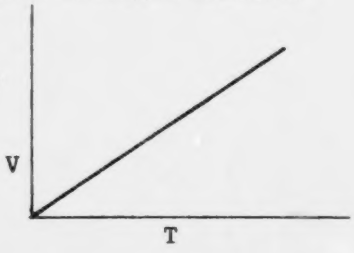
- a. O_3, NO_2 and H_2S
- [✓ b.] CO_2, water vapor, and certain hydrocarbons
- c. NO and molecular oxygen
- d. all of the above.

20. SAMWG (Standing Air Monitoring Work Group) was formed in October 1975 and its major findings include:

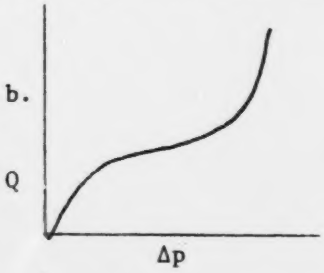
- a. Data being produced was of unknown quality.
- b. Lack of coordination of monitoring activities.
- c. Location of monitors was not systematic
- d. a and c
- e. b and c
- [✓ f.] a, b, and c

21. Select which of the following graphs represents the calibration curve for a critical orifice.

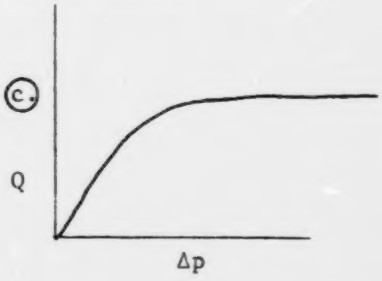
a.



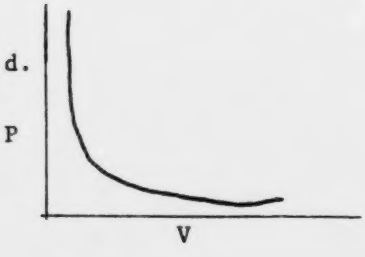
b.



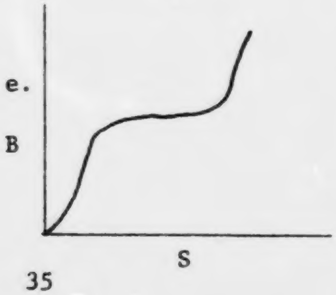
[✓ c.]



d.

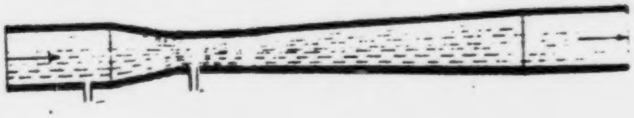


e.

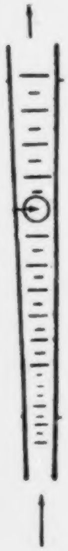


22. Match the following: (from choices 1-10)

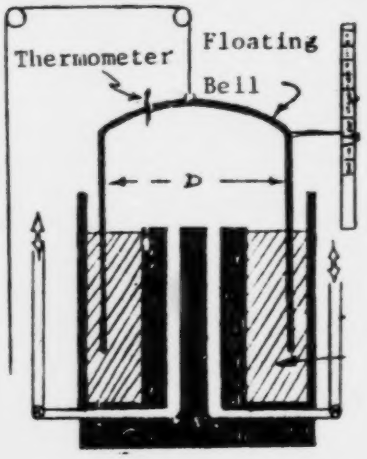
a. 3 spirometer
b. 2 displacement bottle
c. 8 Rootsmeter
d. 9 bubble meter



1

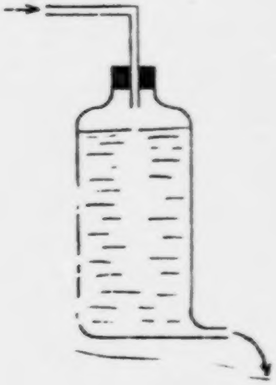


4



3

2



5) the interior contains two or more movable partitions, or diaphragms, attached to the case by a flexible material so that each partition may have a reciprocating motion.

6) "hot wire"

7) standard or "S" type

8) positive displacement meter utilizing mechanical linkages to indicate volume

9) graduated cylindrical glass tube up which a soap film moves

10) primary standard utilizing a mercury seal

23. Identify the following as: (P) primary calibration standards or (S) secondary calibration standards or (I) intermediate standards.

a. __I__ wet-test meter
b. __S__ rotameter
c. __S__ critical orifice
d. __P__ frictionless piston
e. __P__ spirometer

24. Match the following reference methods or principles:

a. __3__ CO

b. __4__ O_3

c. __1__ SO_2

d. __6__ NO_2

(1) pararosaniline
(2) t-butyl mercaptan
(3) NDIR
(4) chemiluminescence with ethylene
(5) flame ionization
(6) chemiluminescence with ozone

25. TRUE OR [✓ FALSE] Grab sampling is illustrated by sampling with a midget impinger at a flow rate of 250 ml/min. for 30 minutes, while integrated sampling is illustrated by sampling with an evacuated container.

26. [✓ TRUE] OR FALSE A bag containing 100 liters of 1.0 ppm NO_2 is an example of static test atmosphere.

27. [✓ TRUE] OR FALSE The regulations on the siting of ambient air quality monitors are contained in the appendixes of 40 CFR 58.

28. [✓ TRUE] OR FALSE A mass flow meter has the advantage of being relatively insensitive to temperature and pressure and therefore does not require corrections for these parameters.

29. [✓ TRUE] OR FALSE Quality assurance can be defined as "quality control for quality control".

30. TRUE OR [✓ FALSE] Direction of flow through a hypodermic needle acting as a limiting orifice has no effect on its flow rate.

NAME Grading Key DATE ____________

COURSE 435

ATMOSPHERIC SAMPLING

PRE-TEST

Answer Sheet

1. ● b c d
2. ● b c d
3. a b ● d
4. a b ● d
5. a b ● d
6. a b ● d
7. ● b c d
8. a b c ●
9. a b ● d
10. a b c ●
11. a ● c d
12. ● b c d
13. a b ● d
14. a b ● d
15. a ● c d
16. a b ● d
17. a b ● d
18. a ● c d
19. a ● c d
20. a b c d e ●
21. a b ● d e

22. a 3
b 2
c 8
d 9

23. a I
b S
c S
d P
e P

24. a 3
b 4
c 1
d 6

25. T ●
26. ● F
27. ● F
28. ● F
29. ● F
30. T ●

NAME______________________ DATE__________________

COURSE 435
ATMOSPHERIC SAMPLING
QUIZ 1

This is a closed-book quiz, use no notes or books, you may use a scientific calculator. You will have 15 minutes to complete this quiz.

Put all answers on the attached answer sheet. Keep the Quiz as a study guide. There is only one correct answer per question.

1. According to the ideal gas law, all of the following are true regarding the volume of a gas except:
   a. volume is directly proportional to temperature
   b. volume is directly proportional to pressure
   c. volume is directly proportional to number of moles of gas present
   d. all ideal gases have the same volume per mole at the same temperature and pressure

2. An ideal gas occupies a volume of 255.0 ml at 20°C and 720 mm Hg. What volume does this gas occupy at EPA standard conditions (25°C and 760 mmHg)
   a. 245.7 ml
   b 232.9 ml
   c. 259.5 ml
   d. 268.4 ml

3. Which of the following is/are primary calibration standard(s)?
   a. frictionless piston
   b. spirometer
   c. wet test meters
   d. a and b
   e. all of the above

4. A ______________________________meter measures volume per unit time (l/min).
   a. velocity
   b. rate
   c. total volume
   d. pitot

5. Which of the following correction factors (C.F.) must be used to correct a measured bubble meter volume to dry conditions ($V_{corr} = V_{measured} \times$ C.F.);

a. $\frac{P_{atm} + P_{H_2O}}{P_{atm}}$

b. $\frac{P_{atm} - P_{H_2O}}{P_{atm}}$

c. $\frac{P_{atm}}{P_{atm} - P_{H_2O}}$

d. $\frac{P_{H_2O} - P_{atm}}{P_{H_2O}}$

6. In order to calibrate a hi-vol air sampler, one must:
   - a. calibrate the orifice unit, then calibrate the visi-float or recording transducer
   - b. calibrate the Rootsmeter against the visi-float
   - c. calibrate the mercury manometer, then calibrate the orifice meter
   - d. calibrate the visi-float, then calibrate the orifice unit.

7. A hi-vol filter sample, after 24 hours of sampling at a constant rate of 45 cfm, weighed 3.157 gms. Initially the filter weighed 3.002 gms. What is the concentration of suspended particulate collected, in $\mu g/M^3$ ($1 ft^3 = 0.02832 m^3$)?
   - a. 175
   - b. 102
   - c. 97
   - d. 85

8. A positive displacement pump is characterized by
   - a. a hyperbolic relationship between pump pressure and flow
   - b. an inverse relationship between pump pressure and flow
   - c. a converse relationship between pump pressure and flow
   - d. a linear relationship between pump pressure and flow

9. A permeation tube maintained at a constant temperature in combination with a dilution system is the most accurate means for generating low level concentrations (ppb levels) of which of the following pollutants?

   a. Ozone
   b. nitrogen dioxide
   c. sulfur dioxide
   d. carbon monoxide
   e. a and b
   f. b and c

10. A dynamic calibration standard is prepared by diluting a stream of concentrated cylinder gas. If the concentrations and flows are as follows, what is the concentration of the calibration gas?

    Tank concentration: 100 ppm

    Flow from tank: 10 ml/min

    Diluent gas flow rate: 100 ml/min

    a. 10.0 ppm
    b. 9.1 ppm
    c. 2.7 ppm
    d. 4.5 ppm

Name ______________________________ Date ___________________________

Answer sheet: Daily Quiz I

Circle the correct answer.

1. a b c d e

2. a b c d

3. a b c d e

4. a b c d

5. a b c d

6. a b c d

7. a b c d

8. a b c d

9. a b c d e f

10. a b c d

NAME Key DATE ____________

COURSE 435
ATMOSPHERIC SAMPLING
QUIZ 1

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1. According to the ideal gas law, all of the following are true regarding the volume of a gas except:
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   - [✓ b.] volume is directly proportional to pressure
   - c. volume is directly proportional to number of moles of gas present
   - d. all ideal gases have the same volume per mole at the same temperature and pressure

2. An ideal gas occupies a volume of 255.0 ml at 20°C and 720 mm Hg. What volume does this gas occupy at EPA standard conditions (25°C and 760 mmHg)
   - [✓ a.] 245.7 ml
   - b 232.9 ml
   - c. 259.5 ml
   - d. 268.4 ml

$V(760\,\text{mmHg}, 25°C) = 255.0\left(\frac{298}{293}\right)\left(\frac{720}{760}\right) = 245.7\,\text{ml}$

3. Which of the following is/are primary calibration standard(s)?
   - a. frictionless piston
   - b. spirometer
   - c. wet test meters
   - [✓ d.] a and b
   - e. all of the above

4. A ______________________ meter measures volume per unit time (l/min)
   - a. velocity
   - [✓ b.] rate
   - c. total volume
   - d. pitot

5. Which of the following correction factors (C.F.) must be used to correct a measured bubble meter volume to dry conditions ($V_{corr} = V_{measured}$ X C.F.);

a. $\frac{P_{atm} + P_{H_2O}}{P_{atm}}$

c. $\frac{P_{atm}}{P_{atm} - P_{H_2O}}$

[✓ b.] $\frac{P_{atm} - P_{H_2O}}{P_{atm}}$

d. $\frac{P_{H_2O} - P_{atm}}{P_{H_2O}}$

6. In order to calibrate a hi-vol air sampler, one must:

[✓ a.] calibrate the orifice unit, then calibrate the visi-float or recording transducer

b. calibrate the Rootsmeter against the visi-float

c. calibrate the mercury manometer, then calibrate the orifice meter

d. calibrate the visi-float, then calibrate the orifice unit.

7. A hi-vol filter sample, after 24 hours of sampling at a constant rate of 45 cfm, weighed 3.157 gms. Initially the filter weighed 3.002 gms. What is the concentration of suspended particulate collected, in µg/M^3 (1ft^3 = 0.02832m^3)?

a. 175

b. 102

c. 97

[✓ d.] 85

$$TSP(\mu g/m^3) = \frac{(3.157 - 3.002)_g (10^6 \mu g/g)}{(45\ cfm)\left(\frac{.02832 m^3}{ft^3}\right)(24\ Hrs.)\left(\frac{60 min}{HR}\right)}$$

$$= 85\ \mu g/m^3$$

8. A positive displacement pump is characterized by

a. a hyperbolic relationship between pump pressure and flow

b. an inverse relationship between pump pressure and flow

c. a converse relationship between pump pressure and flow

[✓ d.] a linear relationship between pump pressure and flow

9. A permeation tube maintained at a constant temperature in combination with a dilution system is the most accurate means for generating low level concentrations (ppb levels) of which of the following pollutants?

a. Ozone
b. nitrogen dioxide
c. sulfur dioxide
d. carbon monoxide
e. a and b
[✓ f.] b and c

10. A dynamic calibration standard is prepared by diluting a stream of concentrated cylinder gas. If the concentrations and flows are as follows, what is the concentration of the calibration gas?

Tank concentration: 100 ppm
Flow from tank: 10 ml/min
Diluent gas flow rate: 100 ml/min

a. 10.0 ppm
[✓ b.] 9.1 ppm
c. 2.7 ppm
d. 4.5 ppm

$$C_1Q_1 = C_2Q_2$$

$$(100\,\text{ppm})(10\,\text{ml/min}) = C_2\,(110\,\text{ml/min})$$

$$C_2 = \frac{(100\,\text{ppm})(10\,\text{ml/min})}{(110\,\text{ml/min})}$$

$$= 9.1\,\text{ppm}$$

Name Grading Key

Date ____________________

Answer sheet: Daily Quiz I

Circle the correct answer.

1. a ● c d e

2. ● b c d

3. a b c ● e

4. a ● c d

5. a ● c d

6. ● b c d

7. a b c ●

8. a b c ●

9. a b c d e ●

10. a ● c d

NAME____________________ DATE____________________

COURSE 435

ATMOSPHERIC SAMPLING

DAILY QUIZ II

This is a closed-book quiz, use no notes or books, you may use a scientific calculator. You will have 15 minutes to complete this quiz.

Put all answers on the attached answer sheet. Keep the Quiz as a study guide. There is only one correct answer per question.

1. SO_2 permeates from a tube at the rate of 0.944 μg/minute at 25.0°C. If the desired concentration you wish to generate is 0.19 ppm, what must be the total flow rate of air? (MW SO_2 = 64g/g-mole)
   a. 0.53 ℓ/min
   b. 1.90 ℓ/min
   c. 2.60 ℓ/min
   d. 1.60 ℓ/min

2. A single dilution system is being used to calibrate an $NO\text{-}NO_2\text{-}NO_x$ analyzer. The flow from the 100.0 ppm tank of NO is 10 ml/min. What dilution flow is needed to obtain a final concentration of 0.25 ppm?
   a. 3990 ml/min
   b. 4000 ml/min
   c. 40 ℓ/min
   d. 2.5 ℓ/min
   e. 25 ℓ/min

3. The concentration of SO_2 (MW = 64 g/g-mole) at standard conditions (25°C and 760mm Hg) was reported as 100 $\mu g/m^3$. This is equivalent to which of the following in parts-per-million. (ppm). (hint, 1ℓ = 10^{-3} m^3)
   a. 100 ppm
   b. .038 ppm
   c. .097 ppm
   d. 10.1 ppm

4. The concentration of nitrogen dioxide was reported as .050 ppm but the collection efficiency was assumed to be 100%. If the actual collection efficiency is 93%, what was the true concentration in ppm?
   a. 0.054
   b. 0.046
   c. 1.5
   d. 0.050

5. A high volume orifice was calibrated in the lab (T = 21.0°C, P=765.0 mmHg) against a rootsmeter. The flow at a pressure drop of 4.0 inches of H_2O was 1.50m^3/min. Later the orifice was used to calibrate a visifloat in the field (T = 40.0°C, P = 749.0 mmHg). What is the flow rate at a pressure drop of 4.0 inches of water at field conditions?

   a. 1.44 m^3/min
   b. 1.50 m^3/min
   c. 1.56 m^3/min
   d. 1.63 m^3/min

6. A particle moving in an air stream with approximately the same velocity as the air stream has more momentum than the volume of air that it displaces. The momentum possessed by a particle in a moving air stream will cause the particle to be deflected less than the air in the vicinity of the particle when the air stream undergoes a sudden change in direction. If the resulting deflection of the particle from the air trajectory around the obstacle is great enough, the particle will strike the obstacle. This is the principle on which ______________________ is based.

   a. precipitation sampling
   b. Isokinetic sampling
   c. gravitational sampling
   d. inertial sampling

7. In the selection of solid adsorbents for gaseous sampling, particularly specialized hydrocarbon sampling, which of the following should be carefully examined?

   a. the potential for in-situ reactions on the adsorbent surface
   b. artifact formation resulting from reaction of the adsorbed material with other gaseous pollutants
   c. the affinity of the adsorbent for water providing a medium for additional reactions of the adsorbed pollutant
   d. all of the above.

8. Which of the following affect the absorption efficiency of a bubbler sampling train?

   a. bubble size
   b. nature of the absorbing medium
   c. flow rate through the sampling train
   d. all of the above

9. The collection efficiency of an impactor can be affected by the following aerosol properties:
   a. acerity, modulation, morphology
   b. operational density, redolence, aspect ratio
   c. particle velocity, particle density, particle size
   d. temperature, refractive index, mass median diameter

10. Which of the following samplers use inertial collection mechanisms?
    a. Andersen sampler
    b. Dichotomous impactor
    c. Cyclone samplers
    d. Cascade impactor
    e. all of the above

Name ______________________________ Date ______________________________

Answer sheet: Daily Quiz II

Circle the correct answer.

1. a b c d

2. a b c d e

3. a b c d

4. a b c d

5. a b c d

6. a b c d

7. a b c d

8. a b c d

9. a b c d

10. a b c d e

NAME Key DATE ____________

COURSE 435
ATMOSPHERIC SAMPLING
DAILY QUIZ II

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   a. 0.53 ℓ/min
   [✓ b.] 1.90 ℓ/min
   c. 2.60 ℓ/min
   d. 1.60 ℓ/min

$$C_{ppm} = \frac{(PR)(MV)}{(MW)(Q_T)}$$

$$Q_T = \frac{(.944)(24.45)}{(64)(.19)} = 1.9\ \ell/min$$

2. A single dilution system is being used to calibrate an $NO\text{-}NO_2\text{-}NO_x$ analyzer. The flow from the 100.0 ppm tank of NO is 10 ml/min. What dilution flow is needed to obtain a final concentration of 0.25 ppm?

   [✓ a.] 3990 ml/min
   b. 4000 ml/min
   c. 40 ℓ/min
   d. 2.5 ℓ/min
   e. 25 ℓ/min

$$C_1Q_1 = C_2Q_2$$

$$(100\,ppm)(10\,ml/min) = (0.25\,ppm)(Q_D + 10\,ml/min)$$

$$\frac{(100)(10)}{(.25)} = Q_D + 10\,ml/min$$

$$3990 = Q_D$$

3. The concentration of SO_2 (MW = 64 g/g-mole) at standard conditions (25°C and 760mm Hg) was reported as 100 µg/m^3. This is equivalent to which of the following in parts-per-million. (ppm). (hint, 1ℓ = 10^{-3} m^3)

   a. 100 ppm
   [✓ b.] .038 ppm
   c. .097 ppm
   d. 10.1 ppm

$$\left(\frac{100\,\cancel{\mu g}}{\cancel{m^3}}\right)\left(\frac{10^{-3}\,\cancel{m^3}}{1\ell}\right)\left(\frac{24.45\,\mu\ell}{\cancel{\mu mole}}\right)\left(\frac{\cancel{\mu mole}}{64\,\cancel{\mu g}}\right) = .038\,ppm$$

4. The concentration of nitrogen dioxide was reported as .050 ppm but the collection efficiency was assumed to be 100%. If the actual collection efficiency is 93%, what was the true concentration in ppm?

   [✓ a.] 0.054
   b. 0.046
   c. 1.5
   d. 0.050

$$\frac{.050}{.93} = .054\,ppm$$

5. A high volume orifice was calibrated in the lab (T = 21.0°C, P=765.0 mmHg) against a rootsmeter. The flow at a pressure drop of 4.0 inches of H_2O was 1.50m^3/min. Later the orifice was used to calibrate a visifloat in the field (T = 40.0°C, P = 749.0 mmHg). What is the flow rate at a pressure drop of 4.0 inches of water at field conditions?

a. 1.44 m^3/min
b. 1.50 m^3/min
[✓ c.] 1.56 m^3/min
d. 1.63 m^3/min

$$Q = 1.5\sqrt{\frac{313}{294} \times \frac{765}{749}}$$
$$= 1.56$$

6. A particle moving in an air stream with approximately the same velocity as the air stream has more momentum than the volume of air that it displaces. The momentum possessed by a particle in a moving air stream will cause the particle to be deflected less than the air in the vicinity of the particle when the air stream undergoes a sudden change in direction. If the resulting deflection of the particle from the air trajectory around the obstacle is great enough, the particle will strike the obstacle. This is the principle on which ____________________ is based.

a. precipitation sampling
b. Isokinetic sampling
c. gravitational sampling
[✓ d.] inertial sampling

7. In the selection of solid adsorbents for gaseous sampling, particularly specialized hydrocarbon sampling, which of the following should be carefully examined?

a. the potential for in situ reactions on the adsorbent surface
b. artifact formation resulting from reaction of the adsorbed material with other gaseous pollutants
c. the affinity of the adsorbent for water providing a medium for additional reactions of the adsorbed pollutant
[✓ d.] all of the above.

8. Which of the following affect the absorption efficiency of a bubbler sampling train?

a. bubble size
b. nature of the absorbing medium
c. flow rate through the sampling train
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9. The collection efficiency of an impactor can be affected by the following aerosol properties:

   a. acerity, modulation, morphology
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   [✓ c.] particle velocity, particle density, particle size
   d. temperature, refractive index, mass median diameter

10. Which of the following samplers use inertial collection mechanisms?

   a. Andersen sampler
   b. Dichotomous impactor
   c. Cyclone samplers
   d. Cascade impactor
   [✓ e.] all of the above

Name Grading Key Date ____________

Answer sheet: Daily Quiz II

Circle the correct answer.

1. a ● c d
2. ● b c d e
3. a ● c d
4. ● b c d
5. a b ● d
6. a b c ●
7. a b c ●
8. a b c ●
9. a b ● d
10. a b c d ●

NAME____________________ DATE____________________

COURSE 435

ATMOSPHERIC SAMPLING

DAILY QUIZ III

This is a closed-book quiz, use no notes or books, you may use a scientific calculator. You will have 30 minutes to complete this quiz.

Put all answers on the attached answer sheet. Keep the Quiz as a study guide. There is only one correct answer per question.

1. Match the following pollutants with their respective reference method or measurement principle:

   a.____________SO_2
   b.____________NO_2
   c.____________CO
   d.____________O_3

   1. non-dispersive infrared
   2. flame ionization
   3. chemiluminescence with ozone
   4. chemiluminescence with ethylene
   5. flame photometry
   6. pararosaniline
   7. secondary coulometry

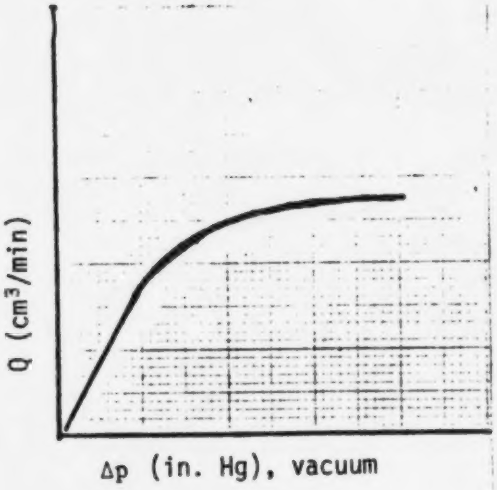
2. An Equivalent Method for the criteria pollutants is best described by which of the following statements?
   a. a method is designated an equivalent method according to the procedures in title 40 part 53 CFR
   b. any method which has been designated an equivalent method is legally equivalent in all respects to the reference method and may be used in SIP monitoring, PSD monitoring and for other federally mandated monitoring.
   c. both a and b
   d. an equivalent method is less accurate than the reference methods and may not be used for legal monitoring.

3. The ReF device is most commonly used to audit a:
   a. wet test meter
   b. high volume sampler
   c. $NO-NO_2-NO_x$ analyzer
   d. tape sampler

4. The primary standard used to calibrate the wet test meter in lab was:
   a. class "A" volumetric flask
   b. rotameter
   c. displacement bottle
   d. none of the above
   e. all of the above

5. The absolute pressure at the inlet of the rotameter (has/has no) effect on the flow rate thru the rotameter.

6.



The curve at the left is a typical calibration curve of a:

a. rotameter
b. wet test meter
c. frictionless piston
d. bubblemeter
e. critical orifice

7. Bag materials (do/do not) affect the stability of a gas standard over time.

8. All of the following have been designated criteria pollutants except:
   a. lead
   b. ozone
   c. trichloroethylene
   d. sulfur dioxide

Name ______________________________ Date __________________________

Answer Sheet: Daily Quiz III

1. a. _____

   b. _____

   c. _____

   d. _____

2. a b c d

3. a b c d

4. a b c d e

5. has or has no

6. a b c d e

7. do or do not

8. a b c d

NAME Key DATE ____________

COURSE 435

ATMOSPHERIC SAMPLING

DAILY QUIZ III

This is a closed-book quiz, use no notes or books, you may use a scientific calculator.

Put all answers on the attached answer sheet. Keep the Quiz as a study guide. There is only one correct answer per question.

1. Match the following pollutants with their respective reference method or measurement principle:

a. 6 SO_2
b. 3 NO_2
c. 1 CO
d. 4 O_3

1. non-dispersive infrared
2. flame ionization
3. chemiluminescence with ozone
4. chemiluminescence with ethylene
5. flame photometry
6. pararosaniline
7. secondary coulometry

2. An Equivalent Method for the criteria pollutants is best described by which of the following statements?

a. a method is designated an equivalent method according to the procedures in title 40 part 53 CFR
b. any method which has been designated an equivalent method is legally equivalent in all respects to the reference method and may be used in SIP monitoring, PSD monitoring and for other federally mandated monitoring.
[✓ c.] both a and b
d. an equivalent method is less accurate than the reference methods and may not be used for legal monitoring.

3. The ReF device is most commonly used to audit a:

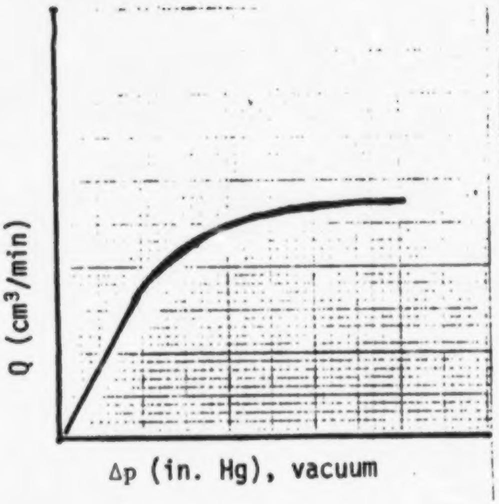
a. wet test meter
[✓ b.] high volume sampler
c. $NO-NO_2-NO_x$ analyzer
d. tape sampler

4. The primary standard used to calibrate the wet test meter in lab was:

[✓ a.] class "A" volumetric flask
b. rotameter
c. displacement bottle
d. none of the above
e. all of the above

5. The absolute pressure at the inlet of the rotameter ([✓ has]/has no) effect on the flow rate thru the rotameter.

6.



The curve at the left is a typical calibration curve of a:

a. rotameter
b. wet test meter
c. frictionless piston
d. bubblemeter
[✓ e.] critical orifice

7. Bag materials ([✓ do]/do not) affect the stability of a gas standard over time.

8. All of the following have been designated criteria pollutants except:

a. lead
b. ozone
[✓ c.] trichloroethylene
d. sulfur dioxide

Name Grading Key Date ____________________

Answer Sheet: Daily Quiz III

1. a. 6

   b. 3

   c. 1

   d. 4

2. a b ● d

3. a ● c d

4. ● b c d e

5. ● or has no

6. a b c d ●

7. ● or do not

8. a b ● d

Name____Date__________________________

COURSE 435

ATMOSPHERIC SAMPLING

Post-Test

This final exam is designed to measure how well the objectives for Course 435 have been met. It is intended to be a CLOSED-BOOK exam, you should use no notes or books. You may use a scientific calculator. Indicate all your answers on the attached answer sheet. You will have 60 minutes to complete this test.

1. A 10ℓ sample of carbon monoxide (MW = 28) is removed from a 100ℓ bag of 50 ppm CO. The remaining concentration of carbon monoxide is:

   a. 40 ppm
   b. 50 ppm
   c. 60 ppm
   d. 42.9 ppm
   e. 45 ppm

2. Corrected to standard conditions of 25°C and 760 mmHg a sulfur dioxide (mw = 64) concentration was reported as .01 ppm. In $\mu g/m^3$, this concentration is:

   a. $26.17\ \mu g/m^3$
   b $42.09\ \mu g/m^3$
   c. $2.67 \times 10^{-3}\ \mu g/m^3$
   d. $2.0\ \mu g/m^3$

3. An ideal gas occupies a volume of 300ml at 35°C and 750mm Hg. At 25°C, 760mm Hg, what volume does this gas occupy?

   a. 294 ml
   b. 306 ml
   c. 286 ml
   d. 314 ml

In items 4-7, select the correct answer from the following list:

a. dry gas meter
b. rotameter
c. wet test meter
d. frictionless piston
e. spirometer
f. displacement bottle
g. mass flow meter
h. critical orifice

Place the letter corresponding to your selection in the space provided for by each question number. Also, circle the type of standard that each device represents. Read the descriptions carefully.

4. _____(primary-intermediate-secondary)

The most accurate standard for flow rate and volume measurements. It functions as follows when gas enters an inlet, a movable bell of precisely known dimensions rises. The bell is supported by a chain and balanced by a counter-weight. It is separated from the stationary tank by a liquid interface. A volume scale, fixed to the side of the bell, and a pointer, attached to the stationary tank, indicate the total volume entering the tank over a given time interval.

5. _____(primary-intermediate-secondary)

It consists of a container which houses a revolving drum which is about two-thirds submerged in water. The drum is divided into four sections, each of which has an inlet and an outlet. When a gas enters the device, it exerts a force that turns the drum clockwise. As one quadrant is filled, the next one rotates into the filling position while the full one begins expelling gas through its outlet.

6. _____(primary-intermediate-secondary)

Sometimes referred to as a variable area flowmeter, it is usually a round glass tube of increasing diameter housing one or more floats which are free to move vertically up and down the tube axis.

7. _____(primary-intermediate-secondary)

As a gas passes across a heated sensor element, some of the heat is removed by the gas (depending on the thermal conductivity of the gas). This cooling of the heated sensor is proportional to the gas velocity and flow rate.

8. A quality assurance program is important in sampling and analyzing atmospheric pollutants because:

a. it is cost effective
b. it adds credibility to the data
c. legal defense of the data is strengthened
d. all of the above
e. none of the above

9. The collection efficiency of an impactor can be affected by which of the following aerosol properties:

a. acerity, modulation, morphology
b. operational density, redolence, aspect ratio
c. particle velocity, particle density, particle size
d. temperature, refractive index, mass median diameter

10. The major EPA siting documents are available for which of the following:

a. SO_2, NO_2, CO, PAN
b. CO, TSP, ozone, SO_2
c. NO_x, PAN, HC, TSP
d. all of the above

11. A wet test meter (WTM) is to be calibrated by the water displacement technique. The WTM is required to be repaired if the error is greater than 5.0%. Is this WTM in working order?

standard = 2.000ℓ
initial WTM reading = 65.816ℓ
final WTM reading = 67.940ℓ

a. yes, the WTM is in good working order.

b. no, the WTM is not in good working order and must be repaired.

12. Which of the following is a disadvantage of the reference method for the determination of total suspended particulates?

a. particulate matter accumulated non-uniformly over the sampling period.
b. artifact formation
c. wind directional sensitivity of the sampler
d. all of the above

13. The reference measurement principle for the detection of ozone in ambient air is based on which of the following?

a. chemiluminescence with ozone
b. chemiluminescence with ethylene
c. sodium-arsenite reaction
d. flame ionization

14. Of the following, which has no ambient air quality standard?

a. CO
b. NO
c. total suspended particulate
d. Lead
e. NO_2

15. Particle bounce and re-entrainment of particles are concerns of which of the following samplers.

- a. Dust fall bucket
- b. Continouous SO_2 analyzer
- c. NDIR analyzer
- d. Cascade impactor

16. The calibration of the hi-volume air sampler requires:

- a. calibration of the mercury manometer, then calibration of the orifice meter
- b. calibration of the orifice meter, then calibration of the mercury manometer
- c. calibration of the Rootsmeter by the visi-float
- d. calibration of the orifice unit, followed by the calibration of the visi-float

17. A primary flow calibration standard is one which:

- a. requires only measurement of physical dimensions to determine volume
- b. requires calibration vs. a secondary standard
- c. permeates at known flow rates
- d. uses mechanical linkage only

18. A secondary flow calibration standard is one which:

- a. requires only measurement of physical dimensions to determine volume
- b. permeates at known flow rates
- c. requires calibration vs. a primary standard
- d. uses mechanical linkage only

19. SO_2 permeates from a tube at the rate of 0.875 μg/minute at 25°C. If the desired concentration you wish to generate is 0.21 ppm, what must be the total flow rate (ignore volume of SO_2 permeating from tube). (MW SO_2 = 64)

- a. 1.25 ℓ/min
- b. 1.59 ℓ/min
- c. 122 ℓ/min
- d. 1.69 ℓ/min

20. The primary consideration given in the development of a monitoring network is:

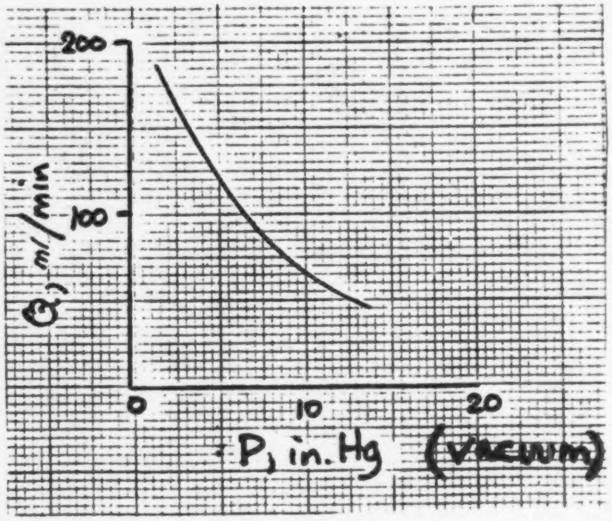
a. what uses will be made of the data?
b. where are the stations to be located?
c. what kind of security is necessary?
d. have enough sites been considered?

21. Hydrocarbons are collected on a solid adsorbent in an area of very high ozone concentration. Which of the following statements is the most probable cause of erroneously high levels of oxygenated hydrocarbons.

a. in-situ reactions of ozone and the hydrocarbon compounds.
b. hydrocarbon-hydrocarbon reactions on the sorbent medium.
c. halogenated hydrocarbons present in the sample gas.
d. high flow rate through the adsorbent device.

22. The following is a curve describing the pump capacity of a

a. centrifugal pump
b. piston pump
c. diaphragm pump
d. metal bellows pump



23. Which of the following statements best describes an ideal gas?

a. equal volumes of different gases under the same conditions of temperature and pressure contain the same number of moles.
b. the pressure is directly related to the volume of an ideal gas.
c. temperature has no effect on an ideal gas
d. hydrogen bonding plays an important role in maintaining the volume of an ideal gas.

24. The Dichotomous Sampler, a "virtual impactor", uses ________________________ to separate particles according to size.

- a. surface tension
- b. inertia
- c. cyclones
- d. filters
- e. none of the above

25. All of the following are adsorbents used in atmospheric sampling except:

- a. polyurethane foam
- b. Tenax-GC®
- c. XAD® resins
- d. TCM solution

26. Which of the following techniques minimizes the effect of broad band interferences in the reference method for the determination of carbon monoxide in ambient air?

- a. an NDIR analyzer that uses two detector cells in series.
- b. an NDIR analyzer that uses two detector cells in parallel.
- c. a second derivative carbon monoxide analyzer.
- d. none of the above.

27. When designing a gas sampling system, which of the following would be considered in choosing an air mover for that system.

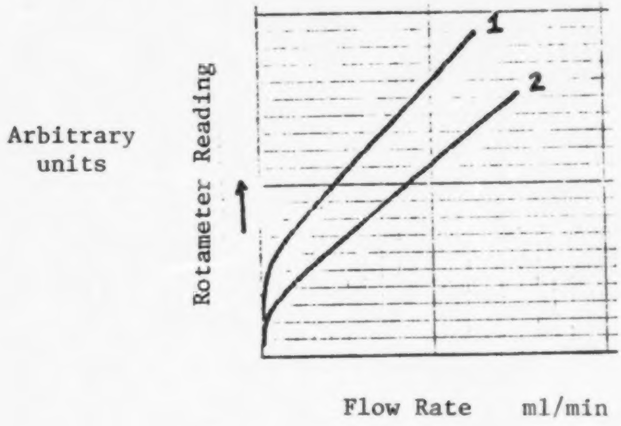
- a. the sampling time required by the system
- b. the sampling rate required by the system
- c. the chemical composition of the gas to be sampled
- d. all of the above
- e. none of the above

28. The Reference Measurement principle for the detection of nitrogen dioxide in ambient air is based on which of the following reactions?

- a. fluorescence reaction of NO_2 and ozone
- b. chemiluminescence reaction of NO and ozone
- c. chemiluminescence reaction of NO_2 and ozone
- d. none of the above

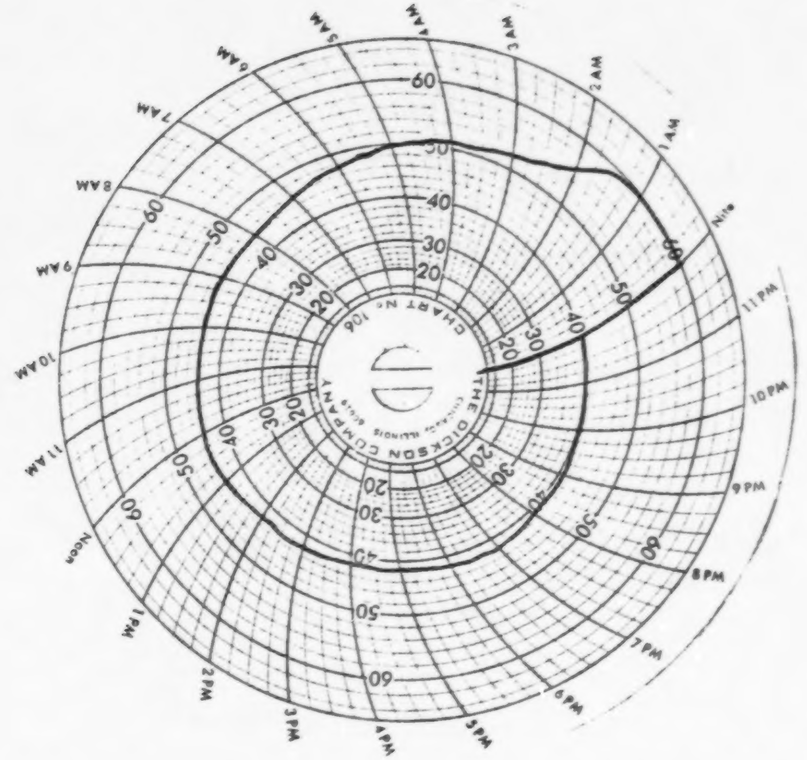
29. Consider the following plot of rotameter reading vs. flow rate. Curve 1 is higher than Curve 2 because:

a. The absolute pressure within the rotameter for Curve 1 was greater than for Curve 2.
b. The absolute pressure within the rotameter for Curve 1 was less than for Curve 2.
c. The correction factor for the wet test meter used to construct Curve 1 was greater than the correction factor for the wet test meter used to construct Curve 2.
d. The correction factor for the wet test meter used to construct Curve 1 was less than the correction factor used to construct Curve 2.



30. A hi-vol sample was collected. The initial weight of the filter was 3.247 gms. After equilibration, the final filter weight was 3.662 gms. From this data, and the attached flow data, what is the TSP concentration, in μg/m^3 for this sample? (Use a 24 hr average for flow data.) (see next page) (1 ft.^{3} = .02832 m^3)

a. 1751 μg/m^3
b. 150.4 μg/m^3
c. 223.7 μg/m^3
d. 6.26 μg/m^3


THE DICKSON COMPANY
CHICAGO, ILLINOIS
CHART No. 106
Nite
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
Noon
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50
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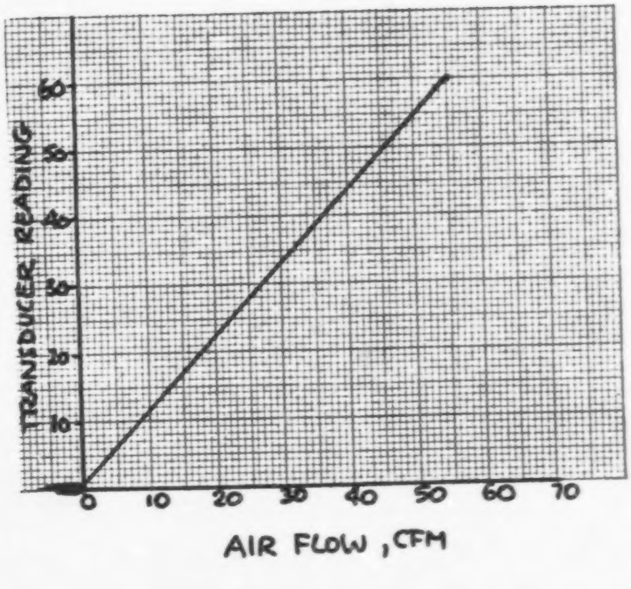
TRANSDUCER READING
60
50
40
30
20
10
0
10
20
30
40
50
60
70
AIR FLOW, CFM

Name ______________________________ Date ____________________

ATMOSPHERIC SAMPLING
Post-Test
Answer Sheet

1. a b c d
2. a b c d
3. a b c d
4. _____ (primary-intermediate-secondary)
5. _____ (primary-intermediate-secondary)
6. _____ (primary-intermediate-secondary)
7. _____ (primary-intermediate-secondary)
8. a b c d e
9. a b c d
10. a b c d
11. a b
12. a b c d
13. a b c d
14. a b c d e
15. a b c d
16. a b c d
17. a b c d
18. a b c d
19. a b c d
20. a b c d
21. a b c d
22. a b c d
23. a b c d
24. a b c d e
25. a b c d
26. a b c d
27. a b c d e
28. a b c d
29. a b c d
30. a b c d

Name Key Date

COURSE 435

ATMOSPHERIC SAMPLING

Post-Test

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1. A 10ℓ sample of carbon monoxide (MW = 28) is removed from a 100ℓ bag of 50 ppm CO. The remaining concentration of carbon monoxide is:

   a. 40 ppm
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   c. 60 ppm
   d. 42.9 ppm
   e. 45 ppm

2. Corrected to standard conditions of 25°C and 760 mmHg a sulfur dioxide (mw = 64) concentration was reported as .01 ppm. In $\mu g/m^3$, this concentration is:

   [✓ a.] 26.17 $\mu g/m^3$
   b 42.09 $\mu g/m^3$
   c. 2.67×10^{-3} $\mu g/m^3$
   d. 2.0 $\mu g/m^3$

$$\left(\frac{.01\,\mu l}{l}\right)\left(\frac{1\,l}{10^{-3}\,m^3}\right)\left(\frac{1\,\mu mole}{24.45\,\mu l}\right)\left(\frac{64\,\mu g}{\mu mole}\right)=\frac{26.17\,\mu g}{m^3}$$

3. An ideal gas occupies a volume of 300ml at 35°C and 750mm Hg. At 25°C, 760mm Hg, what volume does this gas occupy?

   a. 294 ml
   b. 306 ml
   [✓ c.] 286 ml
   d. 314 ml

$$V(760\,mm\,Hg, 25°C) = 300\,ml\left(\frac{750}{760}\right)\left(\frac{298}{308}\right) = 286\,ml$$

In items 4-7, select the correct answer from the following list:

a. dry gas meter
b. rotameter
c. wet test meter
d. frictionless piston
e. spirometer
f. displacement bottle
g. mass flow meter
h. critical orifice

Place the letter corresponding to your selection in the space provided for by each question number. Also, circle the type of standard that each device represents. Read the descriptions carefully.

4. E ✓ (primary-intermediate-secondary)

The most accurate standard for flow rate and volume measurements. It functions as follows when gas enters an inlet, a movable bell of precisely known dimensions rises. The bell is supported by a chain and balanced by a counter-weight. It is separated from the stationary tank by a liquid interface. A volume scale, fixed to the side of the bell, and a pointer, attached to the stationary tank, indicate the total volume entering the tank over a given time interval.

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d. all of the above

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standard = 2.000ℓ
initial WTM reading = 65.816ℓ
final WTM reading = 67.940ℓ

$$\% \text{ ERROR} = \frac{V_m - V_A}{V_A}(100) = \frac{.124\ell}{2.0\ell} = 6.2\%$$

a. yes, the WTM is in good working order.

[✓ b.] no, the WTM is not in good working order and must be repaired.

12. Which of the following is a disadvantage of the reference method for the determination of total suspended particulates?

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a. 1.25 ℓ/min
[✓ b.] 1.59 ℓ/min
c. 122 ℓ/min
d. 1.69 ℓ/min

$$Q_T = \frac{(PR)(MV)}{(MW)(C_{ppm})} = \frac{(.875)(24.46)}{(64)(.21)} = 1.6 \ \ell/\text{min}$$

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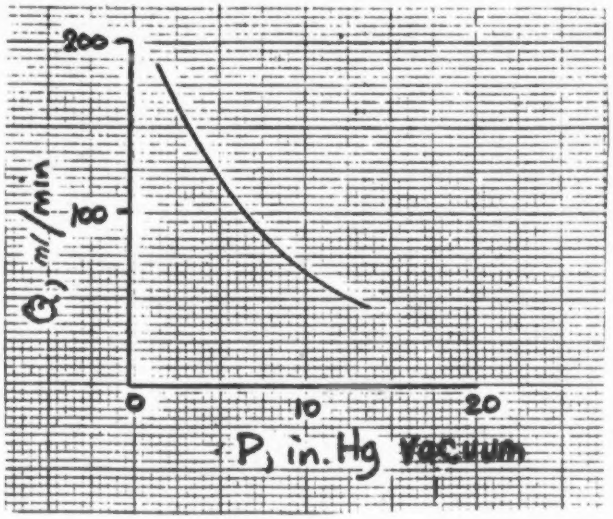

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[✓ b.] inertia
c. cyclones
d. filters
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b. Tenax-GC®
c. XAD® resins
[✓ d.] TCM solution

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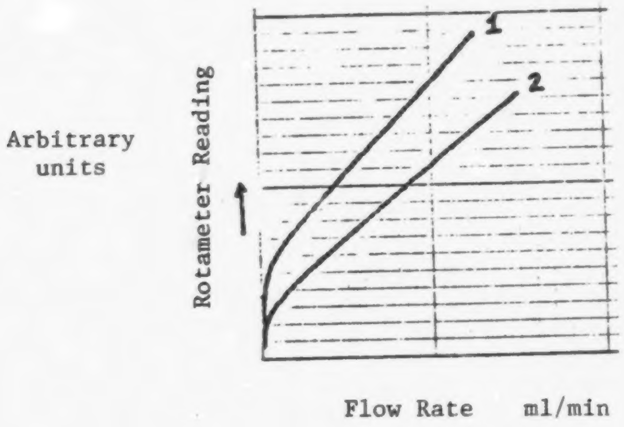
- d. The correction factor for the wet test meter used to construct Curve 1 was less than the correction factor used to construct Curve 2.



30. A hi-vol sample was collected. The initial weight of the filter was 3.247 gms. After equilibration, the final filter weight was 3.662 gms. From this data, and the attached flow data, what is the TSP concentration, in µg/m³ for this sample? (Use a 24 hr average for flow data.) (see next page) (1 ft.³ = .02832 m³)

- a. 1751 µg/m³
- b. 150.4 µg/m³
- [✓ c.] 223.7 µg/m³
- d. 6.26 µg/m³

$$\text{TSP}(\mu g/m^3) = \frac{(3.662-3.247)g\,(10^6\,\mu g/g)}{\left(\frac{55+36\text{ cfm}}{2}\right)\left(\frac{.02832\text{ m}^3}{\text{ft}^3}\right)\left(24\text{ hrs}\right)\left(\frac{60\text{ min}}{\text{hr}}\right)}$$

$$= 223.7\,\mu g/m^3$$

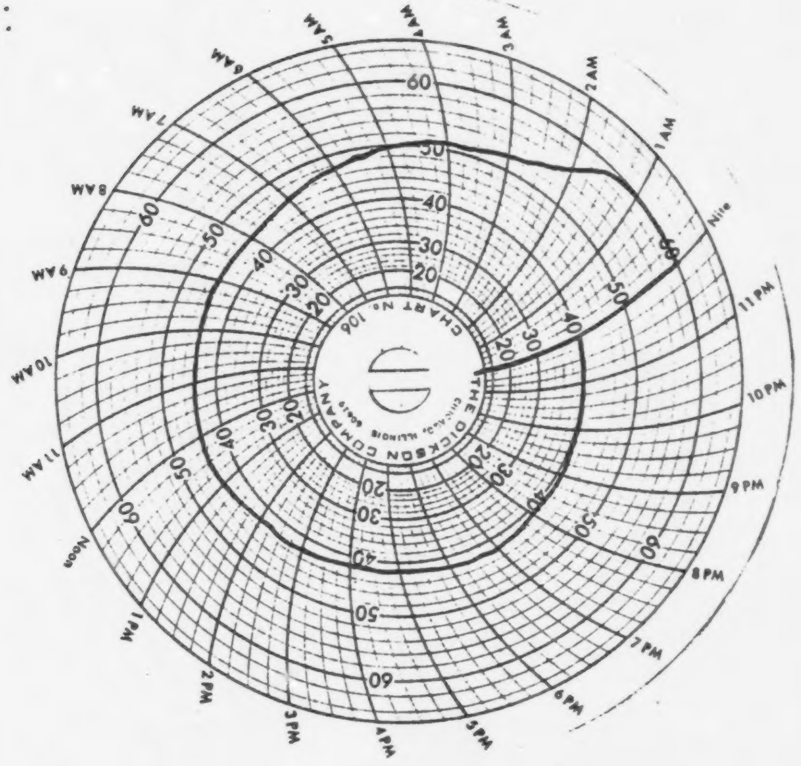


CHART No. 106
THE DICKSON COMPANY
CHICAGO, ILLINOIS
Nite
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
Noon
1 PM
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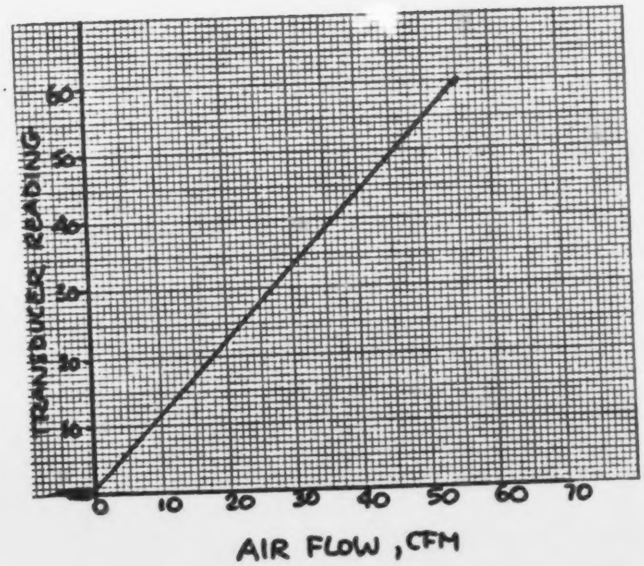
50
60


TRANSDUCER READING
10
20
30
40
50
60
0
10
20
30
40
50
60
70
AIR FLOW, CFM

Name Grading Key Date ____________________

435

ATMOSPHERIC SAMPLING
Post-Test
Answer Sheet

1. a ● c d
2. ● b c d
3. a b ● d
4. E (pr●ry-intermediate-secondary)
5. C (primary-inte●iate-secondary)
6. B (primary-intermediate-sec●ary)
7. G (primary-intermediate-sec●ary)
8. a b c ● e
9. a b ● d
10. a ● c d
11. a ●
12. a b c ●
13. a ● c d
14. a ● c d e
15. a b c ●
16. a b c ●
17. ● b c d
18. a b ● d
19. a ● c d
20. ● b c d
21. ● b c d
22. ● b c d
23. ● b c d
24. a ● c d e
25. a b c ●
26. ● b c d
27. a b c ● e
28. a ● c d
29. a ● c d
30. a b ● d

1

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: REGISTRATION, COURSE INFORMATION, AND PRE-TEST

COURSE: 435-Lesson #1
LESSON TIME: 75 min.
PREPARED BY: Northrop Services, Inc.
DATE: 1/12/79

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

LESSON GOAL: To introduce student to the overall structure of the course.

LESSON OBJECTIVES: At the end of this session the student should know:

1. That this Course 435: Atmospheric Sampling, is presented by__________________________________. (Area Training Centers should recognize their home institution, the Air Pollution Training Institute, and MTIB, Manpower and Technical Information Branch of Control Programs Development Division.)

2. The name of all instructors and their affiliation

3. Phone number where a student may receive messages during the course offering.

4. Course goals and objectives

5. Requirements for passing the course
   a. Completed registration card - Social Security Number optional, required for CEU's, however.
   b. Pre-test
   c. 95% attendance - minimum
   d. Daily quizzes
   e. All laboratory work completed and turned in
   f. Post-test
   g. Minimum overall grade of 70% (See Agenda for breakdown)
   h. Critique

6. Teaching approach used in this course

7. The location of
    a. Restrooms
    b. Refreshments
    c. Laboratories

8. Address and phone number of EPA - Air Pollution Training Institute

U.S. EPA, ERC
APTI, MD20
RTP, NC 27711
919-541-2766
FTS-629-2766

SUPPORT MATERIALS:

1. Student materials package
2. Blackboard and chalk or overhead projector

CONTENT OUTLINE

Page 1 of 3

NOTES

Course: 435 --Lesson 1
Lecture Title: REGISTRATION AND COURSE INFORMATION

I. Introduce instructors
  A. Names and affiliation
  B. Experience
  C. Areas of expertise

II. Institutional setting
  A. If APTI--explain EPA/Contractor relationship
  B. If Area Training Center -- explain relationship with APTI-MTIB and acknowledge source of training materials
  C. Other institutions offering this course--provide statement on their specific situation and acknowledge source of training materials

III. Logistics of the course location - Recognize host for field location
  A. Message phone number
  B. Restrooms
  C. Refreshments and Restaurants
  D. Laboratory Location
  E. Emergency Exits and Emergency alarm system
  F. No smoking in classroom or lab
  G. Parking

A simple floor plan on chalk board or overhead is helpful.

IV. Description of teaching methods
  A. Training
    1. Course directed at training students to perform a specific skilled task.
  B. Instructors
    1. Will be there to help student become trained
    2. Will add their experience and expertise to the training
    3. Encourage questions
  C. Approach
    1. Teach the basic math and sampling techniques
    2. Solve new problems by applying these fundamentals

V. Course Requirements

- A. Completed registration card (Blue Card)
- B. Pre-test
- C. 95% attendance - minimum
- D. All laboratory work completed and turned in
- E. Daily quizzes
- F. Post-test
- G. Minimum overall grade of 70%
- H. Course critique completed and turned in

VI. Materials - have students check that they have

- A. APTI Training Manual: "Atmospheric Sampling"
- B. Student Exercise Manual (2 problem sets and lab exercises)
- C. Agenda
- D. Roster
- E. Chronological Schedule of Courses
- F. Note paper
- G. Registration card
- H. Course and Lesson Objectives

VII. Pre-test and registration

- A. Explain that the pre-test
  - 1. Tests what they know as they enter the course
  - 2. Does not count in the final course grade
  - 3. Will be correlated to post-test grades to measure actual learning in the course
  - 4. Students should not guess at answers on pre-test

- B. Registration card - completely filled out
  Mailing List Form - complete only if you want more than 1 chronological schedule of courses

- C. Begin the pre-test and tell students to take a break after the test

D. Collect all tests, registration cards, and mailing list forms - grade tests promptly and report low, high, and average grades.

E. At this time, it is recommended NOT to review the exam. Answers may be given to review at a later time after the lecture material is covered.

LESSON PLAN

2

AIR POLLUTION TRAINING INSTITUTE

TOPIC: INTRODUCTION TO ATMOSPHERIC SAMPLING

COURSE: 435 - Lesson #2
LESSON TIME: Approx. 1 hr, 15 min.
PREPARED BY: Northrop Services, DATE 1-12-79

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

LESSON GOAL: To introduce the student to the reasons, operations, types, and methods involved in atmospheric sampling. To develop a working knowledge of gas properties, specifically those affecting gas volume by use of the ideal gas law.

LESSON OBJECTIVES: The student will be able to:

1. recall the general reasons for and types of sampling encountered in ambient monitoring.
2. discuss the effects of temperature and pressure on the volume of an ideal gas.
3. recognize the ideal gas law and be able to use it in solving problems in gaseous sampling.
4. define the concept of molar volume and explain its use in atmospheric sampling.
5. convert gas volumes (including the molar volume) to the conditions of standard temperature and pressure currently specified for EPA ambient reference methods.
6. perform rudimentary sampling calculations such as determination of volume sampled, amount of pollutant collected, and conversion of $\mu g/m^3$ to ppm.

SUPPORT MATERIALS AND EQUIPMENT:

1. Objective Handout
2. Slide Projector and 35 mm slides

SPECIAL INSTRUCTIONS:

This lecture begins with a general introduction to ambient sampling although each general concern should be illustrated with a concrete example. The calculations involving the ideal gas law and conversions to EPA Standard conditions are used throughout the course and students having difficulty with these calculations should work Problem Set I carefully. Student participation should be encouraged throughout the lecture by asking class questions and asking students to draw on their experience (although possibly limited) to answer questions.

SELECTED REFERENCES:

Seinfeld, J. H., Air Pollution, McGraw-Hill, Inc., 1975
Barrow, G.M., Physical Chemistry, Chapt. 1 "Properties of Gases", McGraw-Hill, Inc., 1966.
Hollowell, C. D., McLaughlin, R. D., Stokes, J. A., "Current Methods in Air Quality Measurements and Monitoring" IEEE Transactions on Nuclear Science, Vol. NS-72, April 1975.

AIR POLLUTION TRAINING INSTITUTE

CONTENT OUTLINE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Course: 435-Lesson #2
Lecture Title: INTRO. TO ATMOSPHERIC SAMPLING

Page 1 *of* 7

NOTES

Review Lecture objectives with the students

INTRODUCTION TO ATMOSPHERIC SAMPLING

I. Reason for Sampling
to obtain a true representation of the pollutant level at a given point and time (emphasis on true)

L2-1

A. Factors Affecting True Value
1. Conditions of Atmosphere at Sample Time
2. Pollutant Characteristics

L2-2a
b

B. Errors Affecting Sampling
1. Systematic Errors - errors that occur due to repetitive procedure - noted by biased results.
2. Random Errors - nonsystematic errors that occur due to changes in procedure, human error, etc.

L2-3

Note: Ask Students for additional sources of systematic or random errors. Briefly attempt to get positive Student participation.

II. Sampling Operations-
A. Collection Process - gives volume of air sampled
B. Analysis - gives amount of pollutant - together they give air pollution results - concentration of pollutant in mass/volume of air.
C. Manual method (e.g. wet-chemical) sampling - involves two distinct processes - the collection followed by analysis

L2-4a

D. Continuous Method -- Collection and Analysis
1. Performed simultaneously yielding a direct ppm or $\mu g/m^3$ readout.
Continuous monitoring instrumentation--(e.g. $NO-NO_2-NO_x$ chemiluminescent monitors, pulsed fluorescent SO_2 monitors) gives this type of value(s).

L2-4b
L2-5
L2-6

III. Components of a Sampling Train

L2-7

A. Sample Collection Device or Contaminant Detector or Collector.
B. Air Mover
C. Flow Measuring Device

CONTENT OUTLINE

Course: 435 - Lesson #2
Lecture Title: INTRO. TO ATMOSPHERIC SAMPLING

Page 2 *of* 7

NOTES

Illustrate these components on a typical dynamic sampling unit.

L2-8

L2-9

IV. Sampling Types/Methods

- A. Continuous Sample - no collection involved. Air sample analyzed as it is collected
- B. Grab Sample - taken without respect to time -- no flow rates involved. (Usually less than 1 minute)
- C. Condensate - condense pollutant from gaseous phase to liquid phase for measurement.
- D. Impinged Material - uses inertia of pollutant for collection.
- E. Sorbed Materials - collection onto or into collection material.

Illustrate each type with a current application. Ask class for additional examples.

V. Sample Handling Concerns

L2-10

- A. Loss of Materials of Interest — a
- B. Contamination — b
- C. Storage — c
- D. Identification — d

Use specific examples to illustrate the concerns listed. For example, exposure to high temperatures may result in desorption of a pollutant collected on a solid adsorbent. Storage and temperature stability of SO_2 collected by the reference method. Clear identification for legal reasons etc.

This is also a good point to ask for specific examples from students.

VI. Sampling Representativeness, Precision, Accuracy

L2-11

- A. Representativeness - What type sample will best show the representative pollutant concentration. Must consider the time of day, averaging time, season of year, location, etc.
- B. Precision - reproducibility: refers to the extent to which each value in a given set of measurements agrees with the mean of the observations.

L 2-12

- C. Accuracy - correctness refers to the extent to which a given measurement agrees with the true but unknown value of the quantity being measured.

L2-13

INTRODUCTION TO GAS SAMPLING

In Atmospheric Sampling we are primarily concerned with sampling for and in gases. It is, therefore, necessary to understand the basic properties of gases which affect sampling.

I. Factors Affecting Gas Properties

A. Temperature

1. Temperature Scales — L2-14a

a. Fahrenheit	212°	boiling point H_2O
	32°	freezing point H_2O
b. Celsius	100°	boiling point H_2O
	0°	freezing point H_2O

2. Absolute Temperature - temperature measured on the Absolute Scale - which is based on absolute zero - a hypothetical temperature characterized by complete lack of heat (no energy) and equivalent to approx. -273.16°C or -459.67°F.

Gas properties referenced to absolute zero

(a) Rankine corresponds to Fahrenheit(°F) + 459.67

(b) Kelvin corresponds to Celsius (°C)+ 273.16

3. Standard Temperature

Since temperature affects volume of gas it is necessary to have a standard temperature to base all results on.

For Ambient Air Monitoring, EPA's Std. Temp is: — L2-14b

25°C or 298°K

B. Pressure

(3 Types of Pressure)

1. Barometric or Atmospheric Pressure (P_b). Weight exerted by atmospheric air. Standard (P_b) (Pressure measured at sea level and 0°C) = 760mmHg or 1 atmosphere. — L2-15a

2. Gage Pressure (P_g) — L2-15b

Pressure measured on gage in sampling system. Difference in system pressure with respect to atmospheric pressure (maybe positive or negative).

$$P_{abs} = P_b + P_g$$

L2-15c

3. Absolute Pressure (P_{abs} or $\underline{P_a}$)
Pressure of system referenced against no pressure. Gas properties are referenced against absolute pressure.

L2-15d

4. Standard Pressure
EPA Standard = 760 mm of mercury or 1 atmosphere

repeat EPA std. temp. and pressure again.

II. Ideal Gas Laws
Relationship between volume and pressure, temperature, and number of moles of gases.

A. Boyle's Law

Volume is inversely proportional to pressure — L2-16

$V = K(\frac{1}{P})$ or $PV = K$

or

$P_1V_1 = P_2V_2$ @ constant temp

EXAMPLE:
@ constant temp, the volume of gas measured at 745 mmHg was 200 ml, what is the volume of gas at 760 mmHg? — L2-17

(1) $P_1V_1 = P_2V_2$
(2) $(745)(200) = (760)(V_2)$
(3) $V_2 = \frac{(745)(200)}{760} = 196\text{ml}$ — L2-18

B. Charles' Law (Charles'-Gay Lussac) — L2-19

Volume is directly proportional to temperature @ constant pressure

$$V = KT$$

or

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

EXAMPLE: L2-20

@ constant pressure, the volume of a gas measured at $20^\circ C$ was 200 ml. What is the Volume at $25^\circ C$? L2-21

$$\frac{200\text{ml}}{293^\circ K} = \frac{V_2}{298}$$

or

$$V_2 = (200\text{ml}) \times \left(\frac{298}{293}\right)$$

$$V_2 = 203\text{ml}$$

Note ratio >1 since you are increasing the temperature and therefore increasing the volume

L2-22

C. Avogadro's Law

Volume is directly proportional to the # moles present. that is $V = kn$ # moles at constant P and T.

A mole by definition, = the weight of 6.02×10^{23} Gas molecules = MW of the gas. L2-22a

1 mole SO_2 = 64g

1 μ mole = 64μg) # moles = $\frac{\text{\# grams}}{\text{g-MW}}$

Avogadro's Law further implies that:

*Equal volumes of different gases under the same conditions of temperature and pressure contain the same # of moles. L2-23

The preceding laws show the following relationship between Volume and Temperature, Pressure, and # moles of a gas.

Boyles Law — Charles Law — Avogadro's Law

$$V = K_1 \frac{1}{P} = K_2 T = K_3 n$$ L2-24

Combine equations and ——— result is ideal gas Law

$$V = \frac{K_1 K_2 K_3 nT}{P} \text{ where } K_1 K_2 K_3 = R = \text{ideal gas constant}$$

so $V = \frac{nRT}{P}$ or $PV = nRT$ (ideal gas law) L2-25

The concept of molar volume,

Molar volume : The volume that one mole of a gas will occupy at some standard Temperature and pressure L2-26

CONTENT OUTLINE

NOTES

Course: 435 - Lesson #2
Lecture Title: INTRO. TO ATMOSPHERIC SAMPLING

if standard conditions are defined as 25°C and 1 atm or 760 mmHg

Slide L2-27

note Absolute temp. used

$$V = \frac{nRT}{P} = (1\ \text{mole})\frac{(.08205)(298.16^\circ K)}{1\ \text{atm}}$$

(Note that units for R are omitted)

$V = 24.46$ liters at EPA's STP

where $R = 0.03205 \frac{\ell.\text{atm}}{\text{mole.deg}}$

Introduce ppm, and convert $\mu g/m^3$ to ppm example problem

Slide L2-28

EXAMPLE PROBLEM

Sample gives results as

work through problems on blackboard.

$10.6\ \mu g\ SO_2/m^3$

What is this in ppm ?

need to change $\mu g/m^3$ to $\mu\ell/\ell$ which is the same as ppm

$1\ \ell = 10^{-3} m^3$

1 mole SO_2 = 64 grams

1 μmole SO_2 = 64 μ grams

$$\frac{10.6\ \mu g/m^3 \times 10^{-3} m^3}{1\ \text{liter}} \cdot \frac{1\ \mu\ \text{mole}}{64\ \mu\ \text{grams}} = \frac{.1656 \times 10^{-3}\ \mu\ \text{mole}}{1\ \text{liter}}$$

24.46 liters = 1 mole   24.46 μl = 1 μ mole

$$\frac{.1656 \times 10^{-3}\ \mu\ \text{mole}}{1\ell} \times \frac{24.46\ \mu l}{\mu\ \text{mole}} = 4.05 \times 10^{-3}\ \mu l/1$$

or
.004 ppm

EXAMPLE PROBLEM - NO_2 Analysis

Sampling conditions: 25°C and 760 mmHg
Flow Rate: 200 ml/min.
Sampling Time: 24 Hours
NO_2 conc. in Abs. Soln: 3.0 μg/ml
Volume of Abs. Soln: 50 ml
Mol. wt. of NO_2: 46g/g-mole
Collection Eff: 93%

What is conc. in $\mu g/m^3$ and ppm

$$\underset{\text{(conc.)}}{3.0\ \mu g/ml} \bullet \underset{\text{(volume)}}{50\ ml} = \underline{150\ \mu g}\ \text{(mass)}$$

$$\underset{\text{(rate)}}{200ml/min.} \cdot \underset{\text{(time)}}{1440\ min.} = \underline{2.88 \times 10^5\ ml}\ \text{(volume)}$$

$$\frac{\textbf{mass}}{\textbf{volume}} \quad \frac{150\ ug}{2.88 \times 10^5 ml} \bullet \frac{1 \times 10^6 ml}{m^3} = 520\ \mu g/m^3$$

corrected for 93% efficiency $= 520\ \mu g/m^3/.93 = \underline{560\ \mu g/m^3}$

1 μmole = 46 ug

$$\frac{560\ ug}{m^3} \bullet \frac{1\ u\ mole}{46\ ug} = \frac{12.2\ u\ mole}{m^3}$$

24.46 μl = μmole at 25°C and 760 mmHg

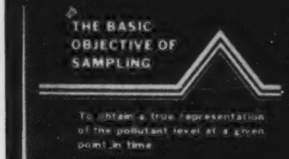
$$\frac{12.2\ u\ mole}{m^3} \bullet \frac{24.46\ \mu l}{\mu\ mole} = 298.53\ ul/m^3$$

$m^3 = 1 \times 10^3\ \ell$

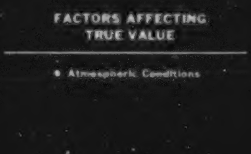
$$\frac{298.53\ u\ell}{m^3} \bullet \frac{m^3}{1x10^3 \ell} = \frac{298.53\ u\ell}{1x10^3 \ell} = .298\ ppm$$

remind students that their homework will give them some chance to practice this

11/79 435 LESSON 2 1

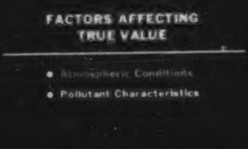

THE BASIC OBJECTIVE OF SAMPLING

To obtain a true representation of the pollutant level at a given point in time


FACTORS AFFECTING TRUE VALUE

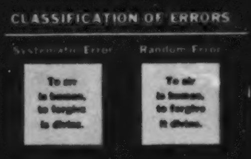
- Atmospheric Conditions

2a


FACTORS AFFECTING TRUE VALUE

- Atmospheric Conditions
- Pollutant Characteristics

2b

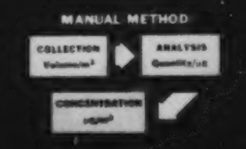

CLASSIFICATION OF ERRORS

Systematic Error | Random Error

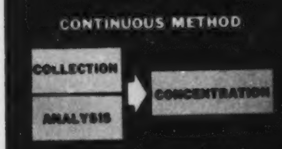
To err is human, to forgive is divine.

To air is human, to forgive it divine.

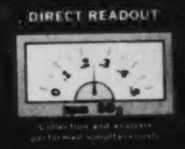
3


MANUAL METHOD

4a

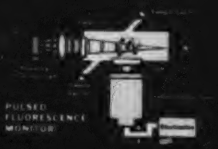

CONTINUOUS METHOD

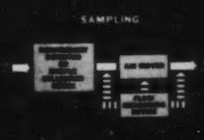
4b


DIRECT READOUT

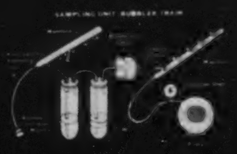
Collection and analysis performed simultaneously

5

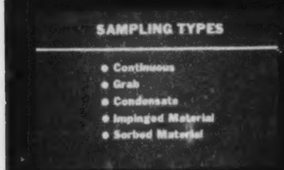



SAMPLING

7

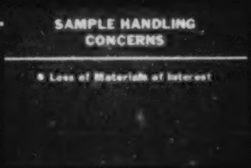

SAMPLING UNIT BUBBLER TRAIN

8


SAMPLING TYPES

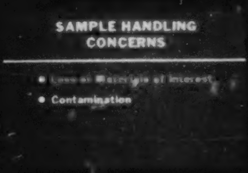
- Continuous
- Grab
- Condensate
- Impinged Material
- Sorbed Material

9


SAMPLE HANDLING CONCERNS

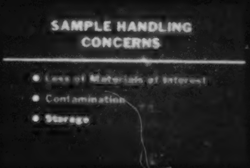
- Loss of Materials of Interest

10a


SAMPLE HANDLING CONCERNS

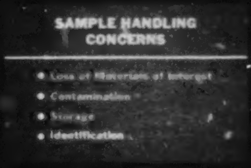
- Loss of Materials of Interest
- Contamination

10b


SAMPLE HANDLING CONCERNS

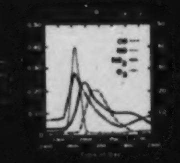
- Loss of Materials of Interest
- Contamination
- Storage

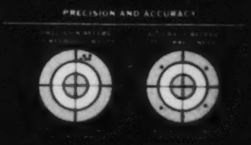
10c


SAMPLE HANDLING CONCERNS

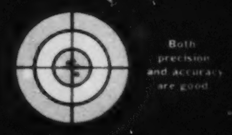
- Loss of Materials of Interest
- Contamination
- Storage
- Identification

10d

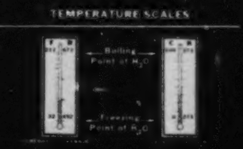

11


PRECISION AND ACCURACY

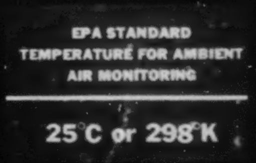
12


Both precision and accuracy are good

13

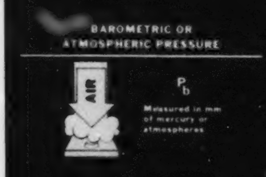

TEMPERATURE SCALES

14


EPA STANDARD TEMPERATURE FOR AMBIENT AIR MONITORING

25°C or 298°K

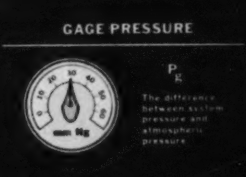
14a


BAROMETRIC OR ATMOSPHERIC PRESSURE

P_b

Measured in mm of mercury or atmospheres

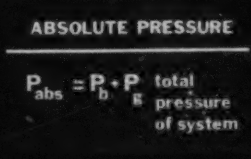
15a


GAGE PRESSURE

P_g

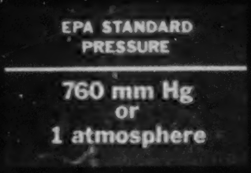
The difference between system pressure and atmospheric pressure

15b


ABSOLUTE PRESSURE

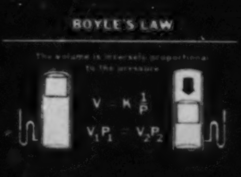
$P_{abs} = P_b + P_g$ total pressure of system

15c


EPA STANDARD PRESSURE

760 mm Hg or 1 atmosphere

15d

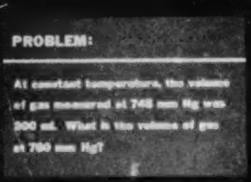

BOYLE'S LAW

The volume is inversely proportional to the pressure

$V = K\frac{1}{P}$

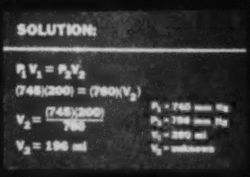
$V_1P_1 = V_2P_2$

16


PROBLEM:

At constant temperature, the volume of gas measured at 748 mm Hg was 200 ml. What is the volume of gas at 760 mm Hg?

17


SOLUTION:

$P_1V_1 = P_2V_2$

$(748)(200) = (760)(V_2)$

$V_2 = \frac{(748)(200)}{760}$

$V_2 = 196$ ml

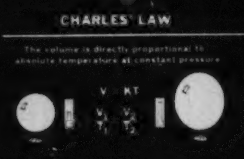
P_1 = 748 mm Hg

P_2 = 760 mm Hg

V_1 = 200 ml

V_2 = unknown

18

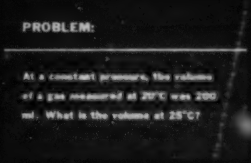

CHARLES' LAW

The volume is directly proportional to absolute temperature at constant pressure

$V = KT$

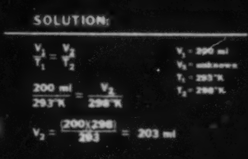
$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

19


PROBLEM:

At a constant pressure, the volume of a gas measured at 20°C was 200 ml. What is the volume at 25°C?

20


SOLUTION:

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$\frac{200 \text{ ml}}{293°K} = \frac{V_2}{298°K}$

$V_2 = \frac{(200)(298)}{293} = 203$ ml

V_1 = 200 ml

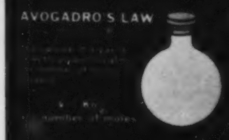
V_2 = unknown

T_1 = 293°K

T_2 = 298°K

21

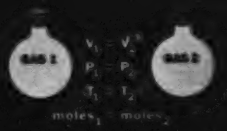
LESSON 2


AVOGADRO'S LAW
V = Kn
n = number of moles

1 mole = molecular weight in grams

$$1 \text{ mole } SO_2 \begin{cases} S \quad 1 \cdot 32 = 32 \text{ g} \\ 2\,O \quad 2 \cdot 16 = 32 \text{ g} \\ \qquad\qquad 64 \text{ g } SO_2 \end{cases}$$

1 μ mole SO_2 = 64 μ g SO_2



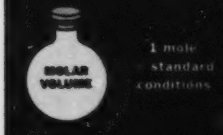
$V_1 = V_2$
$P_1 = P_2$
$T_1 = T_2$
$\text{moles}_1 = \text{moles}_2$

IDEAL GAS LAW

- Volume = $K_1\frac{1}{P} = K_2T = K_3n$
- Combine K_1, K_2, K_3 to be R
- Volume = $\frac{nRT}{P}$ = IDEAL GAS LAW

IDEAL GAS LAW

PV = nRT


MOLAR VOLUME

1 mole
= standard
conditions

$V = \frac{nRT}{P}$ = n = 1 mole
R = .08205
T = standard temperature 298.16°K
P = standard pressure 1 atm

$V = \frac{1 \quad .08205 \quad 298.16 \text{ K}}{1 \text{ atm}}$

V = 24.46 liters at EPA STP

ppm = Parts Per Million

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: GAS MEASURING INSTRUMENTS AND THEIR CALIBRATION, I, II

COURSE: 435 Lesson #3
LESSON TIME: 2 Hours
PREPARED BY: Northrop Services Inc.
DATE: 1/30/79

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

3

LESSON GOAL: To identify and understand the operating principles of various flow measuring devices and their associated calibration procedures.

LESSON OBJECTIVES: After completion of this lecture, the student will be able to:

1) define calibration
2) distinguish between primary, intermediate, and secondary gas flow rate and volume standards
3) distinguish among each of the following flow measurement instruments given operational and/or physical characteristics:
    a) wet test meters
    b) rotameters
    c) critical or limiting orifices
    d) sub-critical orifices
    e) moving bubble meters
4) identify the general characteristics of the following flow measurement instruments:
    a) spirometers
    b) displacement bottles
    c) frictionless pistons
    d) dry test meter
    e) rootsmeters
    f) pitot tubes
    g) mass flow meters
5) Apply appropriate factors to correct volume and flow rates for temperature and pressure
6) Distinguish between volume, rate, and velocity meters

SUPPORT MATERIALS AND EQUIPMENT:

- 35 mm slide projector - required (ATC's)
- Overhead projector
- Blackboard is convenient for explanations

SPECIAL INSTRUCTIONS: None

SELECTED KEY REFERENCES:

(1) Student Course Manual

(2) Gases: B. Airflow Metering Instruments, in "Instrumentation for Environmental Monitoring - Air," pp. 5-12, published by Lawrence Berkeley Laboratories, Feb., 1976.

(3) Nelson, G.O., Controlled Test Atmospheres, pp. 21-50, Ann Arbor Science Publishers, 1971.

CONTENT OUTLINE

AIR POLLUTION TRAINING INSTITUTE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Course 435 - Lesson #3
Lecture Title: CALIBRATION OF AIR MEASURING DEVICES I

Page 3 of 17

NOTES

OBJECTIVES - page 2 of objective handout

refer student to objectives sheet

Objective 3 - indicates "intimate" familiarity with those instruments.

read objectives to students

Objective 4 - will mention only, be able to recognize them, do not have to be familiar with details.

point out difference between Objective 2 & Objective 3

I. CALIBRATION

Definition: The process of establishing the relationship between the output of a measurement process, or portion thereof, and that of a known input.

L3-1

Calibration Approaches: (using volume meter as an example)

1. calibrate meter so that when dial reads 1 liter, 1 liter has indeed passed through the meter.

L3-2

2. calibrate meter so that when 1 liter has passed through the meter, meter reading can be multiplied by some number (correction factor) so that adjusted reading is 1 liter.

POINT: TO DETERMINE QUANTITATIVELY WHAT HAS PASSED THROUGH METER.

II. KINDS OF CALIBRATION STANDARDS

L3-3

1. Primary - can be calibrated simply by measuring dimensions alone.

   example: glass cylinder
   measure diameter, height, determine volume
   by $V=\frac{1}{4}\pi d^2h$

   very accurate (to within ±0.1 or 0.2 percent.)

2. Intermediate - cannot be calibrated by dimensional measurements alone but accurate to within ±0.5 percent, must be calibrated vs. primary standard.

3. Secondary - cannot be calibrated by dimensional measurements alone - must compare with primary standard. Accurate to within a few percent

III. AIR MEASURING DEVICES

A. INTRODUCTION

- total volume meters

- rate meters
- velocity meters

1. total volume meters - measure volume — L3-4

rate meters - measure flow rate

(volume per unit time: example l/min.) — L3-5

2. "rate" meter: volume meter with a timer

Classes of rate meters:

variable pressure meter: change in pressure across constant area.

variable area meter: change in area at constant pressure. — L3-6

3. velocity meters - measure speed

(velocity: length per unit time: example: meters/sec.)

B. VOLUME METERS - Will go over each one individually — L3-7 (read to students)

spirometer	primary standards
moving bubble meter	
frictionless piston	
displacement bottle	
wet test meter	intermediate standard
dry gas meter	secondary standards
rootsmeter	

1. Primary Standards — L3-8

a. Spirometer known as "spirometer"
"gasometer"
"bell prover"
"drum within a drum"

describe spirometer operation

(1) vertical deflection on scalar x cross-sectional area of drum = volume — L3-9

(2) Care:

Drum must be absolutely uniform in cross-sectional area.

counter - weight system must balance out drum so that there are no changes in gas density inside the drum caused by weight of bell and thus affecting pressure.

(3) Strictly a laboratory instrument, very expensive

L3-10 (read to students)

range - 9 to 700ℓ
calibration - $\frac{1}{4}\pi d^2 h$
accuracy - (approximate) ±0.2%
advantages - very accurate
disadvantages - expensive, lab standard only, alignment critical
uses - calibration only

(4) Calibration set-up

L3-11

Typical set-up for calibration of a wet-test meter (WTM) by a spirometer

Necessary to measure P, T in both WTM and spirometer

WHY? Because you will want to correct WTM readings to STP.

b. Frictionless Piston - Primary Standard

L3-12

1. Constant cross-sectional area cylinder with PVC "piston" floating in cylinder - sealed to cylinder sides with mercury (mercury seal)

L3-13

Manufacturer "air gauges" the inside of the cylinder at 1 inch increments to test consistency of i.d. Each system is checked against a standard Frictionless Piston before shipment.

describe operation

2. Rate determined by spacing along cylinder of 2 proximity coils - when mercury seal passes lower coil a timer is activated. When seal passes upper coil, timer is deactivated. Upper coil is movable to change displaced volume.

$$\text{Rate of Flow} = \frac{\text{distance between coils} \times \text{cross-sectional area}}{\text{time}}$$

3. Laboratory Instrument

L3-14

Range - 0.1 - 24 liters/minute

Calibration - $\pi d^2 h/4$

Accuracy ±0.2%

Advantages - convenient, very accurate, easy to calibrate; very little pressure drop

Disadvantages - expensive, lab only, use of mercury as a seal, mercury toxicity

Uses - calibration only

C. Moving Bubble Meter - primary standard

L3-15

- Can be made by competent glass blower
- Simple, can be constructed in your laboratory easily
- Can purchase NBS traceable ones (expensive)
- Can purchase cheaper ones

1. (kind of "frictionless" piston with a soap bubble as piston)

a. Time movement of bubble between two volume marks

$$\frac{V}{t} = \text{Flow} = Q$$

b. Can use cut-off graduated cylinder or inverted Burette, etc.

c. calibration usually accomplished by filling cylinder with water, extracting known amount, and then either use weight of water extracted x density (at lab. T) or measuring volume of extracted water

d. could use $V = \frac{\pi d^2 h}{4}$ but would be inaccurate since i.d. of glass is not very consistent

2. range - Useful 1ml to 1000ml/minute

calibration - by filling with a known volume of liquid

accuracy - ±0.25%

L3-16 (read to students)

advantages - low cost, easy to construct and use

disadvantages - easily broken, must have constantly wet walls, water vapor pressure correction, only good for flowrate $\leq 1\ell$/min

(explain permeation of gas thru bubble: "leak" of gas thru bubble at < 1 ml/min and > 1ℓ/min)

Uses - calibration only.

3. CAUTION: Suppose you are measuring dry air with soap bubble. Film-water used in bubble formation will evaporate into the dry air and thus increase the volume.

Easily corrected, but subtle error that many people do not correct.

a. Correction: Use

$$V_{\text{corrected}}^{\text{std}} = V_{\text{meas}} \times \text{correction factor}$$

$$\text{correction factor} = \frac{P_b - P_{H_2O}}{P_b}$$

L3- 17 a

P_{H_2O} = partial pressure due to water vapor

To correct to standard conditions:

L3-17b

$$V\ \text{std} = V\ \text{corrected} \times \frac{T\ \text{std}}{T\ \text{meas}} \times \frac{P_b}{P\ \text{std}}$$

$$V\ \text{std} = \left[V\ \text{meas} \times \frac{P_b - P_{H_2O}}{P_b} \right] \times \frac{T\ \text{std}}{T\ \text{meas}} \times \frac{P_b}{P\ \text{std}}$$

$$V\ \text{std} = V\ \text{meas} \times \frac{T\ \text{std}}{T\ \text{meas}} \times \frac{(P_b - P_{H_2O})}{P\ \text{std}}$$

b. Example Problem:

A soap bubble traversed a volume of 400ml in 0.75 minutes. If the ambient temperature was 20°C, barometric pressure was 762.3mmHg, what was the flow rate at standard conditions?

L3-18

$$V_{\text{std}} = V_{\text{meas}} \times \frac{T\text{std}}{T_{\text{meas}}} \times \frac{P_b - P_{H_2O}}{P_{\text{std}}}$$

L3-19

P_{H_2O} (at 20°C) = 17.5 mmHg
from "Handbook of Chemistry and Physics"

$$V_{\text{std}} = 400 \times \frac{298}{293} \times \frac{762.3 - 17.5}{760}$$

$$V_{\text{std}} = 399\text{ml}$$

$$Q_{\text{std}} = \frac{V_{\text{std}}}{t} = \frac{399\text{ml}}{0.75\ \text{min}} = 532\ \text{ml/min}$$

L3-20

c. Displacement Bottle - Primary Standard L3- 21a

1. Consists of a bottle filled with water (or some other liquid) and a tube through which air can enter the bottle and a tube through which the liquid is drained out. The entering air displaces the liquid and subsequently enables the measurement of the volume of liquid by having it empty into a primary standard (volumetric flask). The volume of air is thus equal to the volume of liquid that emptied into the volumetric flask. L3-21b

2. range - depends on volumetric flask (Class A) - usually 1-2 liters L3-22

calibration - physical determination of volume of liquid in flask

accuracy - depends on volumetric flask CLASS A - 2000 ml: 0.5ml in 2000 → 0.1%

advantages - easy to assemble and use, inexpensive, highly accurate

disadvantages - water must equilibrate to room conditions before use (24 hrs.), lab only

use - calibration

d. Recap 4 Primary Standards discussed L3-23

SPIROMETER
FRICTIONLESS PISTON
MOVING BUBBLE METER
DISPLACEMENT BOTTLE

2. Intermediate Standard

   a. Wet Test Meter - intermediate standard

      - describe operation of WTM
      - level of water critical

L3-24a

1. SPECIAL FEATURES

   - sight glass - stainless steel spirometer
   - water manometer -gauge pressure in air space above liquid
   - Thermometer - temperature of liquid = temperature of gas

L3-24b

2. range - 1 ℓ to 10ℓ/revolution

   calibration - water displacement, spirometer

   accuracy - ±0.5%

   advantages - widely used, convenient, easy to calibrate

   disadvantages - lab only, water static temp condition, equilibrium time

   use - calibration

L3-25

Do not use WTM for flows > 3 revolutions/min; starts acting as flow limiting device.

3. CAUTION: Since O_2 & N_2 in air is soluble in water, it is necessary to condition water in WTM before using it in the calibration process (operate WTM for ~ 1 hour by pulling air through it prior to use at laboratory conditions to saturate water with O_2 & N_2). If you change from one gas to another, you must re-equilibrate.

Temperature of water in WTM should be at room temperature, fill ~ 24 hours prior to use.

4. For calibration of wet test meter use displacement bottle (a primary standard)

L3-26

   a. (DESCRIBE CALIBATION: Procedure to be used in Lab)

1. Use class A Volumetric Flask to Collect Water

2. From laboratory data calculate percent error
   if much more than ± 2% error, WTM needs to be adjusted.
3. Note P_b, T on lab data sheet

   Must correct for Δp across meter L3-27a

   Δp measured by U tube manometer

   $$V_{std} = V_{meas} \times \frac{T_{std}}{T_{meas}} \times \frac{P_b - \Delta p}{P_{std}}$$ L3-27b

If Δp measured in inches H_2O, convert to P_b units before subtraction.

If P_b is measured in mmHg, Δp converted by

$$\Delta p\text{, mmHg} = \frac{\Delta p\text{, in } H_2O}{13.59 \frac{\text{in } H_2O}{\text{in Hg}}} \times \frac{25.4 \text{ mmHg}}{\text{in Hg}}$$ L3-28

4. EXAMPLE PROBLEM:

   2.600ℓ of air at 27°C, 750 mmHg were passed through a WTM, $\Delta p = 0.35$ in H_2O. What is the volume of air passed through the meter at STP? L3-29

   $$V_{std} = V_{meas} \times \frac{T_{std}}{T_{meas}} \times \frac{P_b - \Delta p}{P_{std}}$$ L3-30a

   $$\Delta p = \frac{0.35 \text{ in } H_2O}{13.59 \frac{\text{in } H_2O}{\text{in Hg}}} \times 25.4 \frac{\text{mmHg}}{\text{in Hg}} = 0.65\text{mmHg}$$ L3-30b

   $$V_{std} = 2.600\ell \times \frac{298^\circ K}{300^\circ K} \times \frac{(750 - 0.65) \text{ mmHg}}{760\text{mmHg}}$$ L3-30c

   $$= 2.600\ell \times 0.99 \times 0.99$$

   $$V_{std} = 2.550\ell$$

3. Secondary Standards

L3-31

a. Dry Test Meter - Not often used in ambient sampling, but used often in source sampling.

L3-32

1. Describe Operation of DTM
    - (1) front bellows fills
    - (2) back bellows fills
    - (3) front bellows empties
    - (4) back bellows empties
    - GO TO (1)

2. range 1-100 ℓ/rev.

L3-33

calibration (displacement bottle, spirometer)

accuracy ± 1% full scale

advantages light, field usable, rugged, easy to read

disadvantages - calibration deteriorates with time

use - sampling, calibration

New read out made more accurate < ± 1 or 2%

L3-34
(cover briefly: considered more extensively in Hi-Volume lecture)

b. Rootsmeter - secondary standard

Calibration standard for hi-volume sampling

(1) Explain operation -

(hitch: rootsmeter operates at about 60 cfm, difficult to find standard to calibrate against in normal laboratory)

L3-35

Manufacturer calibrates against very large spirometer or Frictionless Piston

(2) range -0.3 cfm to several thousand cfm

L3-36

calibration - very large spirometers and frictionless pistons

accuracy - (± 1%)

advantages - durable, high flow rate with low pressure drop, stays in calibration

disadvantages - Weight, lab only

use - Specific in calibrating high vol.

**************** STOP FOR LUNCH *****************

AIR POLLUTION TRAINING INSTITUTE

CONTENT OUTLINE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Course: 435 - Lesson #3
Lecture Title: Calib. of Air Measuring Devices II

Page 12 *of* 17

NOTES

Recap what happened in Cal. I.

C. Rate Meters

1. Introduction L3-37a

a. Measure Flow (volume/time) L3-37b

Variable Pressure - Secondary Standards

- conventional orifice
- critical/limiting orifice

Variable Area - Secondary Standards

- Rotameters L3-38

2. Variable Pressure Meters

a. Orifice Meters - Secondary Standards

Explain what an orifice meter is - constriction in a pipe

If increase Δp across orifice (constriction) flow increases with Δp up to a maximum flow called the critical flow (sonic flow). At this point speed of gas = speed of sound. L3-39

Same orifice can be critical and non-critical depending on Δp.

Must protect orifices from material that will clog them.

(1) Conventional Orifice - used as flow controlling and measuring devices - can vary Δp to get different flows (up to a certain point).

(2) Critical or Limiting Orifice

General "Rule of Thumb" - Flow through any orifice is critical when P upstream = 2 x P downstream and when cross-sectional areas of tube is 25 times the area of the constriction.

L3-40

Note: differences between critical limiting orifices include diameter, taper, and others

Critical pressure determined by:

Orifice construction

wall roughness

relative size of the orifice

L3-41

cross-sectional area vs. approach cross-sectional area

etc.

- to obtain critical flow:
  (1) pressurize upstream, or
  (2) de-pressurize downstream side (evacuate)

(will use this approach in lab)
L3-42

- Lab set-up (similar)

4A.3.18 (describe and locate components)

- hypodermic needles can be used as limiting orifices

L3-43

- gage inversely proportional to flow

L3-44

- length of hypodermic has minor effect on flow

- Direction of flow through a hypodermic needle acting as a limiting orifice has an obvious effect on its flow rate.

Kotrappa, et. al., "Evaluation of Critical Orifices made from sections of Hypodermic Needle" Ann Occup. Hyg., Vol. 20, pp 189-194, 1977.

(3) range : typical ranges 0.1 ℓ/min-10 ℓ/min — L3-45

calibration: primary standard (bubble meter, wet test meter)

accuracy: ± 3% (hypodermic needles)

advantages: inexpensive, simple, maintains constant flow

disadvantages: only one critical flow rate possible, high pressure drop, large capacity pump required

use: sampling

QUESTIONS? — Ask for questions about orifices

3. Variable Area Meter - secondary standard — L3-46a

Rotameter - common instrument

a. simple construction - theoretical operation complex - basically air below float becomes dense enough to lift float

float, tapered glass tube — L3-46b

3 forces acting

downward: gravity — L3-47

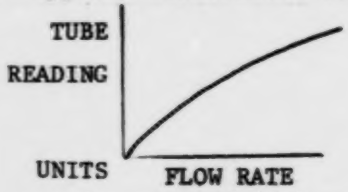
upward: buoyancy, viscous drag — L3-48

(1) Buoyancy

Buoyancy of stainless steel--aerodynamic shape (minor force in the case of a stainless steel ball)

(2) Viscous drag (affinity gas has for sides of float-will attempt to drag sides with it as it passes--also will cause a small pressure drop on downstream side of ball)

- when three forces balance, ball will float in gas
- variable area because tube is tapered: as float rises area between float and tube increases and gas velocity decreases and viscous drag decreases; as float falls area between float and tube walls decreases.
- area varies, pressure remains constant.
- typical calibration curve.



L3-49

b. range .005 ℓ/min - 45 ℓ/min

L3-50

calibration - primary standard, wet test meter, moving bubble meter, mass flow meter

for atmospheric sampling applications

accuracy ±5 to ±10%

advantages - light, portable, direct flow readings, ease of operation, useful in field.

disadvantages- correction for temperature and pressure or calibrate under conditions to be used

use - Sampling

c. Corrections for T and P: Rotameter

Corrections for T and P: Rotameter

Correction process differs for rate meters from that of the process for volume meters

Describe to the students how to read a float in a rotameter i.e. read center of float.

$$\text{Volume meters} \Longrightarrow \underset{\substack{\uparrow \\ \text{Corrected Volume}}}{V_{corr}} = V_{meas} \times \frac{P_{meas}}{P_{std}} \times \frac{T_{std}}{T_{meas}}$$

flow correction differs from volume correction :

L3-51
Note for students--square root used for flow corrections

$$\underset{\text{(corrected)}}{Q_{T_2P_2}} = Q_{T_1P_1} \underset{\substack{\nearrow \\ \text{Comes from Bernoulli's Theorem}}}{\sqrt{\frac{P_1T_2}{P_2T_1}}}$$

better to avoid calculated corrections: calibrate at the conditions under which you intend to use the rotameter!

in the laboratory, you will calibrate a rotameter using this set-up

rotameter is downstream of bubblers, at reduced pressure

L3-52

you will calibrate at two different upstream pressures, and plot the calibration curves

you will essentially be investigating the effect of pressure (T will be constant, more or less) on the flow

L3-53

IMPORTANT: the rotameter should be calibrated in the configuration (sampling train) in which it is used.

4. Velocity Meters L3-54

Not commonly used in ambient sampling, and then primarily as calibration devices

- pitot tube often used in source testing - primary standard

a. Mass Flowmeter - secondary standard L3-55

1. Measure mass flow by transfer of heat

Components - Transducer and electronics package

Since heat transfer is sensed, mass flow is registered, not volume flow. But volume is output electronically.

Heat transfer not affected by changes in P, T. BUT affected by changes in gas (mass flow of helium registers differently than mass flow of air because of different thermal properties of helium and air).

Calibrate for the gas to be used.

b. Operation: Gas flows across heated element in transducer, thereby cooling it. Mass flow is determined by amount of energy required to re-heat the element to its original temperature thru a kind of Wheatstone Bridge arrangement.

Somewhat expensive

c. range 0-50,000 SCCM (Std. cubic centimeters per minute) L3-56

calibration wet test meter, spirometer, frictionless piston

accuracy - ± 5%

response time - (5 sec. full scale)

advantages - No correction necessary over wide range of T & P.

disadvantages - Requires electrical power, limited to non-explosive gases, particulate buildup will alter response, minimum threshold flow ≈0.5% full scale reading

SUMMARY

IMPORTANT - air measuring instruments (for this course) L3-57

- WTM
- rotameter
- orifices L3-58

L3-59

conventional
critical

Meters
- volume meters
- rate meters
- velocity meters

Standards
- primary
- intermediate
- secondary

uses

CLASS QUESTIONS

What is an example of a volume meter? rate meter? velocity meter?

What is an example of a primary standard? Intermediate standard? Secondary standard?

Any other questions?

11/79 935 LESSON 3

3

CALIBRATION

Known Input
Output

1

APPROACHES TO CALIBRATION

2

CALIBRATION STANDARDS

PRIMARY	calibrate by dimensional measurement alone
INTERMEDIATE	calibrated against greater accuracy standards
SECONDARY	

3

AIR MEASURING DEVICES

- Total Volume Meters
  - measure volume

AIR MEASURING DEVICES

- Total Volume Meters
  - measure volume
- Rate Meters
  - measure flow rate
  - two classes
    - variable pressure
    - variable area

5

AIR MEASURING DEVICES

- Total Volume Meters
  - measure volume
- Rate Meters
  - measure flow rate
  - two classes
    - variable pressure
    - variable area
- Velocity Meters
  - measure linear speed

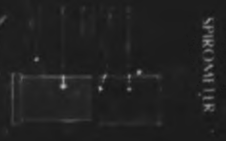
6

VOLUME METERS

PRIMARY	spirometer moving bubble frictionless piston displacement bottle
INTERMEDIATE	wet test meter
SECONDARY	dry test meter rootsmeter

7

8



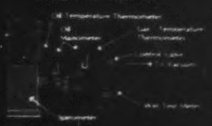
9

SPIROMETER

Range	5 – 750 liters
Calibration	physical measurement $V = \frac{\pi d^2 h}{4}$
Accuracy	± 0.2 %
Advantages	highly accurate
Disadvantages	expensive, lab only, alignment critical
Use	calibration only

10

CALIBRATION SET - UP



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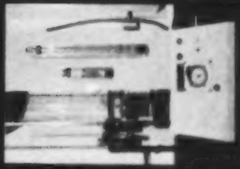

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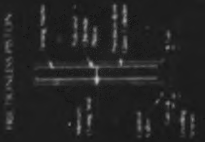


13

FRICTIONLESS PISTON

Range	0.1 – 24 liters/minute
Calibration	physical measurement $V = \frac{\pi d^2 h}{4}$
Accuracy	± 0.2 %
Advantages	more convenient than spirometer, easier to calibrate, highly accurate, little pressure drop
Disadvantages	expensive, use of mercury, lab only
Use	calibration only

14

MOVING BUBBLE METER

Normal Range:	1 – 1000 ml/minute
Calibration:	physical measurement of displaced liquid
Accuracy:	≤ ± .25%

16

CORRECTION FOR WATER VAPOR

$$V_{corrected} = V_{meas} \times \text{correction factor}$$

$$\text{correction factor} = \frac{P_b - P_{H_2O}}{P_b}$$

P_{H_2O} = partial pressure due to H_2O

17a

CORRECTING TO STANDARD CONDITIONS

$$V_{STD} = V_{corrected} \times \frac{T_{STD}}{T_{meas}} \times \frac{P_b}{P_{STD}}$$

$$V_{STD} = V_{meas} \times \frac{P_b - P_{H_2O}}{P_b} \times \frac{T_{STD}}{T_{meas}} \times \frac{P_b}{P_{STD}}$$

$$V_{STD} = V_{meas} \times \frac{T_{STD}}{T_{meas}} \times \frac{P_b - P_{H_2O}}{P_{STD}}$$

17b

PROBLEM:

A soap bubble traversed a volume of 400 ml in .75 minutes. If ambient temperature was 20° C and the barometric pressure was 762.1 mm Hg what was the flow rate at standard conditions?

18

SOLUTION

Step 1: Determine volume at standard conditions

$$V_{STD} = V_{meas} \times \frac{T_{STD}}{T_{meas}} \times \frac{P_b - P_{H_2O}}{P_{STD}}$$

$V_{meas} = 400$ ml
$T_{meas} = 293°$ K
$T_{STD} = 298°$ K
$P_b = 762.1$ mm Hg
$P_{STD} = 760.0$ mm Hg
$P_{H_2O} = 17.5$ mm Hg at 20°C

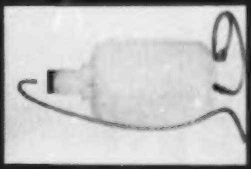
$$V_{STD} = 400 \times \frac{298}{293} \times \frac{762.1 - 17.5}{760.0} = 399 \text{ ml}$$

19

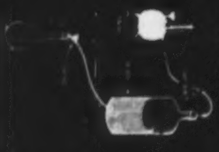
Step 2: Determine Rate at STP

$$\text{Rate} = Q_{STD} = \frac{V_{STD}}{\text{time}} = \frac{399 \text{ ml}}{0.75 \text{ min}} = 532 \text{ ml/min}$$

20



21a



21b

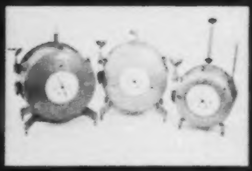
DISPLACEMENT BOTTLE

Range	usual 1 – 2 liters
Calibration	physical determination of volume of liquid in volumetric flask ± 0.1%
Accuracy	depends on volumetric flask
Advantages	easy to assemble and use highly accurate, inexpensive
Disadvantages	water must be equilibrated to room conditions, lab only
Use	calibration

22

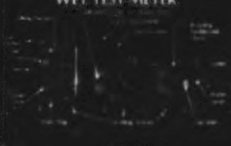
PRIMARY STANDARDS

23



24a

WET TEST METER



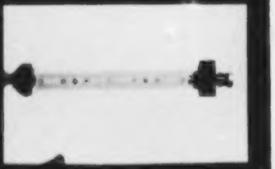
24b

WET TEST METER

Range	1 – 10 liters/revolution
Calibration	water displacement or spirometer
Accuracy	±0.5% optimum, ± 1.0% usual
Advantages	widely used, easy to calibrate, convenient
Disadvantages	lab use only, equilibrium time
Use	calibration

25

26



27

1/79 4P LESSON 2 4

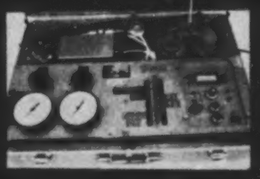
$$V_{std} = V_{meas} \times \frac{T_{std}}{T_{meas}} \times \frac{P_b - \Delta p}{P_{std}}$$

$$\Delta p\ mm\ Hg = \frac{\Delta p\ in\ H_2O}{13.59\ \frac{in\ H_2O}{in\ Hg}} \times 25.4\ \frac{mm\ Hg}{in\ Hg}$$

PROBLEM:

2,600 liters of air at 27° C and 750 mm Hg were passed through a wet test meter with a Δp = 0.35 inches H_2O.

What is the volume of air passed through the meter at STP?



$$V_{std} = V_{meas} \times \frac{T_{std}}{T_{meas}} \times \frac{P_b - P_{H_2O}}{P_{std}}$$

V_{meas} = 2,600 liters
T_{meas} = 27° C + 273° = 300° K
P_b = 750 mm Hg
P_{H_2O} = Δp

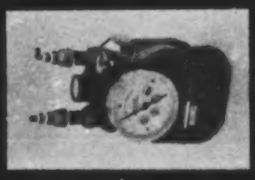
$$p = \frac{0.35\ in\ H_2O}{13.59\ \frac{in\ H_2O}{in\ Hg}} \times \frac{25.4\ mm\ Hg}{in\ Hg}$$

p = 0.65 mm Hg

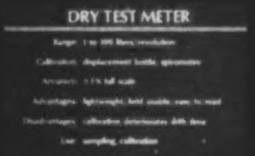
V_{std} = 2,600 liters × $\frac{298°K}{300°K}$ × $\frac{750 - 0.65\ mm\ Hg}{760\ mm\ Hg}$

V_{std} = 2,600 × 0.99 × 0.99

V_{std} = 2,550 liters



DRY TEST METER



DRY TEST METER

Range: 1 to 100 liters/revolution
Calibration: displacement bottle, spirometer
Accuracy: ± 1% full scale
Advantages: lightweight, field usable, easy to read
Disadvantages: calibration deteriorates with time
Use: sampling, calibration

ROOTSMETER OPERATION

ROOTSMETER

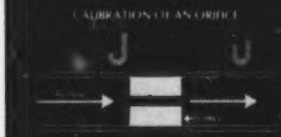
Range:
Calibration:
Accuracy:
Advantages:
Disadvantages:
Use: specific for calibration of hi-vol samplers

FLOW RATE

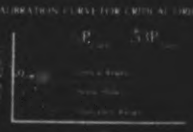
$$Q = \frac{V}{T}$$

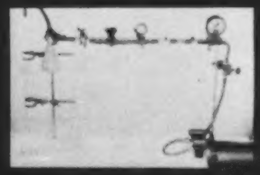
RATE METERS

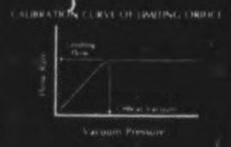
- Variable Pressure
  - Conventional Orifice
  - Critical / Limiting Orifice
- Variable Area
  - Rotameter

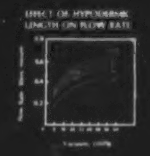


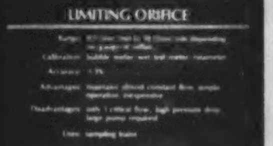
CONDITION FOR CRITICAL ORIFICE





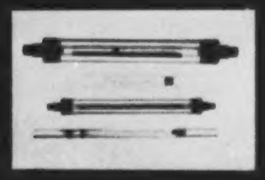


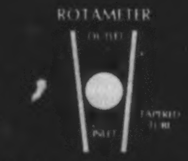


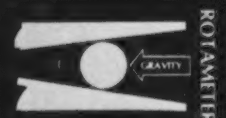


LIMITING ORIFICE

Range:
Calibration: bubble meter, wet test meter, rotameter
Accuracy:
Advantages:
Disadvantages:
Uses: sampling trains







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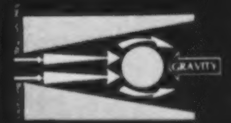

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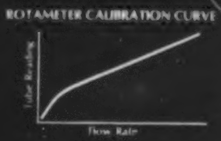

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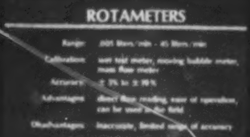

ROTAMETERS

Range: .005 liters/min - 45 liters/min
Calibration: wet test meter, moving bubble meter, mass flow meter
Accuracy: ± 3% to ± 10%
Advantages: direct flow reading, ease of operation, can be used in the field
Disadvantages: inaccurate, limited range of accuracy
Use: sampling trains

50

CORRECTIONS FOR T AND P: ROTAMETER

$$Q_{T_2P_2} = Q_{T_1P_1}\sqrt{\frac{P_1T_2}{P_2T_1}}$$

51

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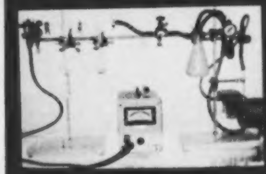

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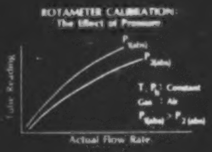
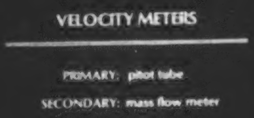


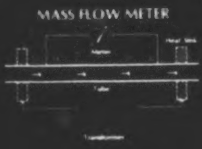
ROTAMETER CALIBRATION: The Effect of Pressure



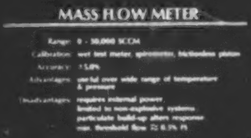
VELOCITY METERS

PRIMARY: pitot tube

SECONDARY: mass flow meter



MASS FLOW METER



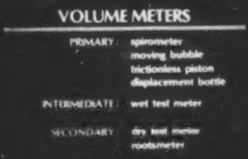
MASS FLOW METER

Range:	0 - 30,000 SCCM
Calibration:	wet test meter, spirometer, frictionless piston
Accuracy:	±5.0%
Advantages:	useful over wide range of temperature & pressure
Disadvantages:	requires external power limited to non-explosive systems particulate build-up alters response min. threshold flow ≈ 0.3% FS

5'

AIR MEASURING DEVICES

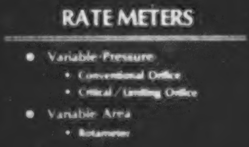
57



VOLUME METERS

PRIMARY:	spirometer moving bubble frictionless piston displacement bottle
INTERMEDIATE:	wet test meter
SECONDARY:	dry test meter rootsmeter

53



RATE METERS

- Variable Pressure
  - Conventional Orifice
  - Critical / Limiting Orifice
- Variable Area
  - Rotameter

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LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: HIGH VOLUME METHOD

COURSE: 435 - Lesson #4
LESSON TIME: 1 Hour
PREPARED BY: Northrop Services, Inc.
DATE: 1/31/79

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Lesson Goal: To develop an understanding of the procedures involved in performing, calibrating and auditing the high volume method for particulate sampling.

Lesson Objectives:

The student will be able to:

1. Briefly describe the components of a standard high volume sampler.
2. List the procedure for properly obtaining a high volume sample of suspended particulate.
3. Outline the procedure for calibrating a high volume calibration orifice using a rootsmeter.
4. Recall and use the method for recalculating the orifice calibration curve when different temperature and pressures are involved.
5. Describe and use the procedure for calibrating a high volume unit containing a visifloat or transducer.
6. Discuss briefly the audit procedure for the high volume sampler.
7. Calculate the total suspended particulate concentration for a high volume sample, given filter weights, flow rate, sampling time.
8. Identify the common interferents (errors) associated with total suspended particulate measurement using the reference high volume method.

Support Material and Equipment:

1. Objective Handout

   This is in Blue Folder

2. Carousel Projector with Slides
3. Handout of Federal Register, Vol. 36, No. 84, Part II, Friday, April 30, 1971. Appendix B "Reference Method for the Determination of Suspended Particulates in the Atmosphere (High Volume Method)

   This is in course manual

Special Instruction: This is the method students will perform in Laboratory 1.

Selected Reference:

Federal Register, Vol. 36, No. 84, Part II, Friday, April 30, 1971. Appendix B. "Reference Method for the Determination of Suspended Particulates in the Atmosphere (High Volume Method)".

TITLE: HIGH VOLUME METHOD

The PURPOSE of this lecture is to develop an understanding of the procedures involved in performing, calibrating and auditing the high volume method for particulate sampling.

GO OVER OBJECTIVES OF LECTURE

INTRODUCTION - High Volume Air Sampling L4-1

Historically, suspended particulates (coal dust, fly ash, smoke, etc.) have been associated with air pollution, as a readily identifiable form along with photochemical haze. Sampling for particulates in the air is a basis of modern ambient air monitoring. The Federal Reference Method is contained in 40CFR50 (Appendix B) which is in the Course Manual. L4-2

The High Volume Air Sampler is probably the most used method of ambient monitoring - over 20,000 are in use.

Particulates are one of the seven criteria pollutants for national primary and secondary ambient air quality standards

High Volume Sampling data is used for a variety of purposes including
- Evaluating compliance with air quality standards L4-3a
- Determination of air quality trends L4-3b
- Public Health studies L4-3c
- Development and Evaluation of control measures L4-3d
  and others (Ask students for others)

THE HIGH VOLUME SAMPLER

--Development - Developed by Silverman (1948). Used a vacuum cleaner motor with a 4 in. filter and filter holder. Refined later (1950's) to take larger filter. 1957 General Metal Works redesigned the sampler to USPHS specifications to look as it does today. L4-4 L4-5

-- Sampler - Modified electric motor. Stainless steel or aluminum filter holder. Filter 8x10 in., (20.3x25.4cm) exposed surface 7x9 in. (63 in^2 or 406.5cm^2). Operated at 40-60 cfm (1.1-1.7m^3/min) collects particles up to 100 microns (Stokes equiv. diameter) (usually 0.1-30 microns) L4-6

L4-7

-- Shelter - Shelter provides protection, allows unrestricted access of ambient air without direct impingement of particles (fallout or dustfall). Shelter also eliminates particles larger than 120μm by inertia. Peaked roof acts as a plenum, above the filter, distributing the particles evenly across the face of filter. Shelter is integral part of sampler, usually built of wood, aluminum, stainless steel. L4-8

-- Constant Flow Samplers - Constant flow hi-vol samplers are designed to eliminate the problem of flow decreasing with filter loading; several types are used.

-- MSA Fixt - Flo Sampler - uses automatic compensating damper - as resistance increases the bypass damper is closed causing increased suction.

-- Pressure Sensitive Regulators - uses pressure sensitive switch at exhaust port - when resistance increases, exhaust pressure decreases causing switch to increase the voltage to the motor which increases suction.

Cover these briefly, as most use the mass flow (thermal) controllers now

-- Series Flow Regulator - a spring loaded piston inserted in the throat of the filter holder. The piston has an annular opening which is increased in size as the spring relaxes due to lowering resistance.

-- Mass Flow Tranducers - Most widely used method. A mass flow meter probe is inserted into the throat of the Hi-Vol sampling head. This probe senses the mass flow of air past it. Electronic circuitry adjust power (current) going to hi-vol motor to keep mass flow constant. As discussed in earlier lecture--mass flow meters are insensitive to temperature and pressure fluctuations. If the mass flow is calibrated at standard temperature and pressure, then airflow through hi-vol is measured at STP.

L4-9

-- Maintenance

1. Replace brushes periodically, approx. 30-60 runs Based on records of performance

L4-10

2. "Buck or Boost" transformer to increase brush life, reduces voltage ~ 25% (this reduces flow rate-must maintain at least 40 cfm not greater than 60 cfm)
3. Clean or replace flowmeter and flowmeter tubing.
4. Clean and replace face plate gasket, a major area of flow leakage (point out signs of wear)

L4-11

5. Clean inside shelter cover.

Filter Media

L4-12

Influenced by objectives of the sampling program. Glass fiber filters are the most commonly used. Not perfect but generally meet requirements. Must be careful of filter pH and uniformity ...also reactions with and/or on filter. Difficult to remove particles for microscopic study. Artifact formation (SO_2 and NO_2). Usually not possible to use for silica, calcium, sodium, potassium due to high blank levels. Should take random blank level readings to subtract out such constituents. Other media include cellulose and plastics (e.g. teflon). Mention that EPA will supply free of charge glass fiber filters from their filter bank to all federally mandated monitoring efforts. Mention also used in lead analyses as well.

L4-13

CONTENT OUTLINE

Course: 435 - Lesson #4
Lecture Title: High Volume Method

	NOTES
HIGH VOLUME SAMPLING PROCEDURE	
-- Choose Filter Media	L4-14a
-- Inspect filter for tears, holes, etc. - this can be done on a photo light table.	L4-14b
-- Affix ID number - make sure not to damage filter, usually stamped on.	L4-14c
-- Equilibrate filter - must be done in a clean room or constant temp. and humidity chamber - equilibrate at 70-75° F for at least 16 hrs. before weighing at less than 50% relative humidity. Atmosphere should be free of acidic or basic gases, especially HF.	L4-14d
-- Weigh Filter - to nearest milligram using a calibrated balance. Balance should be calibrated with NBS weight before and after weighing batch of filters. Careful not to bend or fold filter. standard lab balances have special filter weighing tray attachments.	L4-14e
-- Record Filter Weight - should keep balance log beside balance to document weights, calibration, etc. After weighing, filter should be inserted in protective glassine envelope and put in folder - unfolded - can load in cartridge.	L4-14f
-- Install filter on High Volume Sampler - make sure filter is centered and that faceplate gasket is in good condition. Use equal pressure in applying faceplate - can be done indoors if sampler is in a windy environment.	L4-14g L4-15
-- Record pertinent data - can be filled in on filter folder. Should contain: (a) Filter No. (b) Station No. (c) Sampler No. (d) Starting Time (e) Initial Flow Rate (f) Date and Operators' Initials (g) Summary of Conditions (Meteorology, Construction Activities, etc.) - give example.	L4-14h
-- Sample for 24 hrs. - typical sample is 12 midnight to 12 midnight. Can be shorter for heavier loading.	L4-14i
-- Record final flow rate after 5 min. of warm-up. (this flow rate should be the actual flow rate-as read off calibration curve)	L4-14j
-- Record stop time and elapsed time and summary of conditions.	
-- Remove Filter. Note if edge is sharp between soiled and clean part of filter. If not, may need to replace gasket. If other than minimal, note on data sheet and possibly discard filter.	L4-14k
-- Inspect for holes, tears, foreign matter (such as insects), etc.	L4-14l
-- Fold Filter (lengthwise) soiled surface to soiled surface and place in envelope and then in folder.	L4-16 L4-14m
-- Re-equilibrate to Weighing Room Atmospheric Conditions- 24 hrs.	L4-14n

--Reweigh filter; record final weight and net weight plus other pertinent information. L4-14o

Mention elapsed time meters for timing sample runs, transducers for flowrate, to determine if a shut down occurred during run. L4-17

SUMMARIZE HI-VOL METHOD

1. Filter L4-18
2. Vacuum Cleaner Motor
3. Weighing

Calculation of Total Suspended Particulates

$$\text{TSP } (\mu g/m^3) = \frac{\text{mass}_f - \text{mass}_i}{\left(\frac{Q_i + Q_f}{2}\right) \text{X } 1440 \text{ min./24 hr. x } t} \text{ X } 10^6 \ \frac{\mu g}{g}$$ L4-19

(Can use other averaging method)

mass_f = Final mass of Hi-Vol Filter (grams)

mass_i = Initial mass of Hi-Vol Filter (grams)

Q_f = Final Flowrate - Corrected to True Flowrate (m^3/min)

Q_i = Initial Flowrate - Corrected to true flowrate (m^3/min)

10^6 = Conversion of grams to micrograms

t = Sampling time in hours

Results in $\mu g/m^3$

CALIBRATION OF THE HIGH VOLUME CALIBRATION ORIFICE L4-20

Will perform this in Laboratory A L4-21a

-- Description of Calibration Unit - 7.6 cm I.D. 15.9 cm long. Pressure Tap 5.1 cm from one end. End plate has hole 2.9 cm in diameter - for orifice calibration . L4-21b
Five resistance plates to simulate different particulate loadings. 5,7,10,13, & 18 holes; 18-hole plate represents clean filter.

-- Rootsmeter - serves as a "primary" standard dry gas meter, even though an secondary standard. Measures volume of air passed through calibration orifice.

-- Calibration Procedure L4-22

(1) Hi-vol motor is attached to exhaust outlet of the rootsmeter

(2) Mercury manometer is placed on rootsmeter pressure tap

(3) Orifice unit is attached (resistance plate in place) to inlet of rootsmeter

(4) Water manometer is attached to orifice pressure tap

(5) Given volume of air is pulled through unit - rootsmeter, by Hi-Vol motor. L4-23

(6) Time elapsed (min), mercury pressure drop (mmHg), water pressure drop (in H_2O), volume of air passed are recorded.

(7) Repeated for each resistance plate

(8) Barometric pressure and room temp. are recorded

-- Calculation of Calibration Curve

Pressure reduced in Rootsmeter, so true Volume must be obtained.

First correct air volume sampled to true air volume using: L4-24

$$V_b = \frac{(P_b - P_m)}{P_b} (V_m)$$

V_b = True Air Volume at Atmospheric Conditions, (m^3)

P_b = Barometric Pressure, (mm Hg)

P_m = Pressure drop across inlet of primary standard, (mm Hg)

V_m = Volume of air measured by primary standard, (m^3)

Then determine the air flowrate by:

$$Q = \frac{V_b}{T}$$ L4-25

Q = True Air flowrate (m^3/min.)

V_b = True Air Volume, (m^3)

T = Time of Flow, (min.)

This is calculated for each resistance plate and graphed on log-log graph paper (2x3 cycle) L4-26

This is the Orifice Calibration Curve for this particular orifice. Should not use curves supplied with orifices - you should produce your own and check theirs with yours.

--Recalculation of Orifice Calibration Curve - (Due to change in atmospheric conditions) - If calibration orifice is used to calibrate a hi-vol station where atmospheric conditions are significantly different. Rule of thumb - 15% change in pressure with a 100% change in temperature yields 15% error. The calibration curve needs to be adjusted. Formula for recalculation: L4-27 L4-28

$$Q_{new} = Q_{cal} \left(\frac{T_{new} P_{cal}}{T_{cal} P_{new}} \right)^{½}$$

Q_{new} = New Flowrate at New Atmospheric Conditions

Q_{cal} = Flowrate calculated previously

$T_{new} P_{new}$ = New Temperature and Pressure

$T_{cal} P_{cal}$ = Previous Temp. and Pressure

SHOW THE STUDENTS A SAMPLE PROBLEM AND WORK THROUGH IT FOR THEM L4-29

Sample Problem - Correction of Hi-Vol Orifice Calibration Curve L4-30 a L4-30b

The Hi-Vol orifice was calibrated at 24°C and 762 mmHg. From the curve of flow rate vs Δp, the flow rate is 1.28 m^3/min when Δp_1 = 6.0 in H_2O. What is the new flow rate Q_{new}, T_{new} = 10°C and P_{new} = 770 mmHg?

SOLUTION:

$$Q_{new} = Q_{cal} \left(\frac{T_{new}\ P_{cal}}{T_{cal}\ P_{new}} \right)^{1/2}$$

$Q_{cal} = 1.28\ m^3/min\ @\ \Delta p_1 = 6.0\ in.\ H_2O$

$T_{new} = 10^oC + 273 = 283^oK$

$P_{new} = 770\ mmHg$

$T_{cal} = 24^oC + 273 = 297^oK$

$P_{cal} = 762\ mmHg$

$$Q_{new} = 1.28\ m^3/min \left(\frac{283 \times 762}{297 \times 770} \right)^{1/2}$$

$$= 1.28\ m^3/min\ (.971)$$

$$= 1.24\ m^3/min$$

$$Q_{new} = 1.24\ m^3/min\ @\ \Delta P_1 = 6.0\ in\ H_2O$$

This represents only 1 point on new calibration scale. L4-31

CONTENT OUTLINE

Course: 435 - Lesson #4
Lecture Title: High Volume Method

Page 7 of 8

NOTES

CALIBRATION OF HIGH VOLUME UNIT (with visifloat or transducer flowrate devices)

Slides for visifloat calibration
L4-32
L4-33
L4-34
L4-35

-- Procedure for Calibration

1. The filter holder assembly is removed and replaced with the calibration orifice unit.
2. A water manometer is placed on the orifice pressure tap.
3. The hi-vol motor is run with each resistance plate in place.
4. For each run a pressure drop (in. H_2O) reading is recorded, and a visifloat or transducer reading is recorded.
5. The relative transducer/visifloat flow reading is graphed against the actual flowrate derived from the orifice calibration curve, to give a calibration curve for this particular hi-vol unit.

Slides for transduce calibration
L4-36
L4-37
L4-38
L4-39

HIGH VOLUME SAMPLING ACCURACY AND PRECISION

Affected by several factors:

L4-40

-- Sampler Operating Characteristics - sampler drop in flowrate due to filter loading introduces some error, line voltage fluctuations cause errors, flowrate chosen (i.e., 20 cfm, 60 cfm, etc.) can affect result

-- Peaked roof causes wind direction dependence

-- Accuracy of Calibration

-- Filter Characteristics - reactivity and size range of particulates

-- Location of the Sampler - both site and height

-- Nature and Concentration of Particles Sampled - artifact formed from SO_2 and NO_2.

-- Particulate matter accumulated non-uniformly over sampling period and adsorption and absorption of water vapor.

Can correct many flow problems with constant flow Hi-Vol.

-- Idle periods show gain in mass.

HIGH VOLUME REFERENCE AUDIT PROGRAM

Developed by EPA and NBS to field check calibration orifices. Uses a plastic box with a series of holes which act as a subcritical limiting orifice. Each ReF has a K value which is used to determine the accuracy of the Q values for the calibration orifice unit. ReF consist of:

(a) Plastic box which attaches directly to hi-vol filter holder.

(b) Set of resistance plates which fit inside box in a recessed area above filter holder inlet.

(c) Windscreen - to prevent pressure fluctuations at inlet

(d) Pressure tap and water manometer

SUMMARIZE WITH A REVIEW OF OBJECTIVES

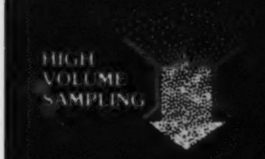
QUESTIONS?

END OF LECTURE

Show reference device
L4-41

Refer to lab 1 experiment 2 for procedures
L4-42

11/79 435 LESSON 1



code of federal regulations
40 CFR 50
Appendix B

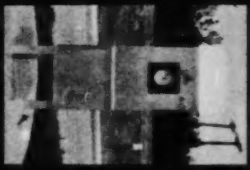
PURPOSES OF HI-VOL SAMPLING DATA
- Evaluating compliance

PURPOSES OF HI-VOL SAMPLING DATA
- Evaluating compliance
- Determining air quality trends

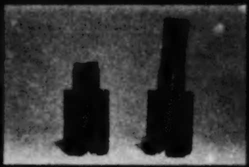
PURPOSES OF HI-VOL SAMPLING DATA
- Evaluating compliance
- Determining air quality trends
- Public health studies

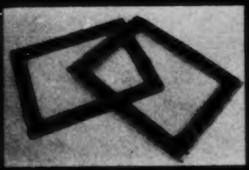
PURPOSES OF HI-VOL SAMPLING DATA
- Evaluating compliance
- Determining air quality trends
- Public health studies
- Development and evaluation of control measures

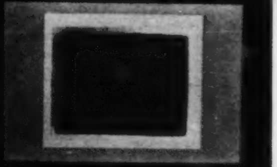
4

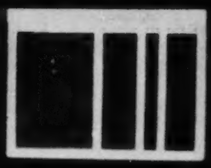


HIGH
VOLUME
SAMPLER
IN A
SHELTER









HI-VOL SAMPLING PROCEDURE
- Choose media

14a

HI-VOL SAMPLING PROCEDURE
- Choose media
- Inspect filter

HI-VOL SAMPLING PROCEDURE
- Choose media
- Inspect filter
- Affix I.D. number

HI-VOL SAMPLING PROCEDURE
- Choose media
- Inspect filter
- Affix I.D. number
- Equilibrate

HI-VOL SAMPLING PROCEDURE
- Choose media
- Inspect filter
- Affix I.D. number
- Equilibrate
- Weigh filter

HI-VOL SAMPLING PROCEDURE
- Choose media
- Inspect filter
- Affix I.D. number
- Equilibrate
- Weigh filter
- Record weight

HI-VOL SAMPLING PROCEDURE
- Choose media
- Inspect filter
- Affix I.D. number
- Equilibrate
- Weigh filter
- Record weight
- Install

15

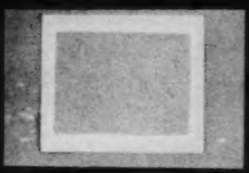
HI-VOL SAMPLING PROCEDURE (Cont.)
- Record data
  - filter number
  - station number
  - sampler number
  - starting time
  - initial flow rate
  - date and operator's I.D.
  - conditions summary

HI-VOL SAMPLING PROCEDURE (Cont.)
- Sample

HI-VOL SAMPLING PROCEDURE (Cont.)
- Sample
- Note final flow rate and elapsed time

HI-VOL SAMPLING PROCEDURE (Cont.)
- Sample
- Note final flow rate and elapsed time
- Remove filter

HI-VOL SAMPLING PROCEDURE (Cont.)
- Sample
- Note final flow rate and elapsed time
- Remove filter
- Inspect filter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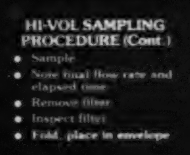
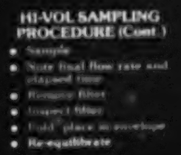
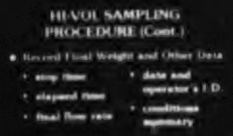
1/79 435 LESSON 4 #7


HI-VOL SAMPLING PROCEDURE (Cont.)
- Sample
- Note final flow rate and elapsed time
- Remove filter
- Inspect filter
- Fold, place in envelope

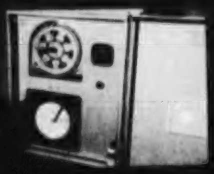
16a


HI-VOL SAMPLING PROCEDURE (Cont.)
- Sample
- Note final flow rate and elapsed time
- Remove filter
- Inspect filter
- Fold, place in envelope
- Re-equilibrate

16b


HI-VOL SAMPLING PROCEDURE (Cont.)
- Record Final Weight and Other Data
  - stop time
  - elapsed time
  - final flow rate
  - date and operator's I.D.
  - conditions summary

16c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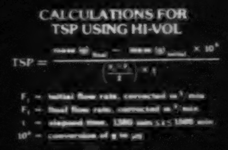
TOTAL SUSPENDED PARTICULATE
High Volume Method

18


CALCULATIONS FOR TSP USING HI-VOL

$$TSP = \frac{mass(g)_{final} - mass(g)_{initial} \times 10^6}{\left(\frac{F_i + F_f}{2}\right) \times t}$$

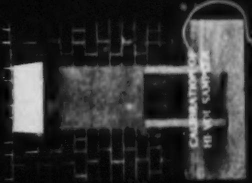
F_i = initial flow rate, corrected m³/min

F_f = final flow rate, corrected m³/min

t = elapsed time, 1380 min ≤ t ≤ 1500 min

10^6 = conversion of g to μg

19



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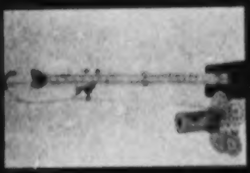
21a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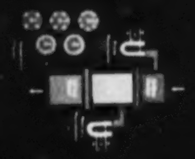
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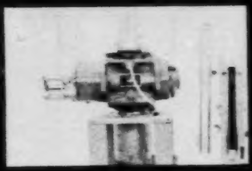
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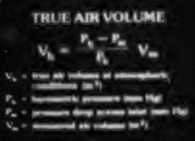

TRUE AIR VOLUME

$$V_b = \frac{P_b - P_m}{P_b} V_m$$

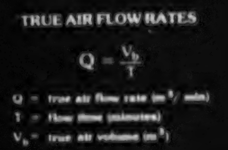
V_b = true air volume at atmospheric conditions (m³)

P_b = barometric pressure (mm Hg)

P_m = pressure drop across inlet (mm Hg)

V_m = measured air volume (m³)

24


TRUE AIR FLOW RATES

$$Q = \frac{V_b}{T}$$

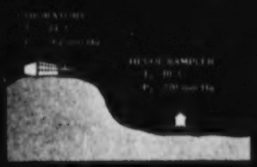
Q = true air flow rate (m³/min)

T = flow time (minutes)

V_b = true air volume (m³)

25

26



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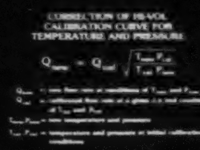

CORRECTION OF HI-VOL CALIBRATION CURVE FOR TEMPERATURE AND PRESSURE

$$Q_{new} = Q_{cal}\sqrt{\frac{T_{new} P_{cal}}{T_{cal} P_{new}}}$$

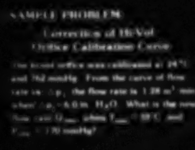
Q_{new} = new flow rate at conditions of T_{new} and P_{new}

Q_{cal} = calibrated flow rate at a given Δp and conditions of T_{cal} and P_{cal}

T_{new}, P_{new} = new temperature and pressure

T_{cal}, P_{cal} = temperature and pressure at initial calibration conditions

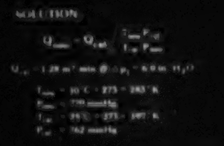
28


SAMPLE PROBLEM:

Correction of Hi-Vol Orifice Calibration Curve

The tested orifice was calibrated at 24°C and 762 mmHg. From the curve of flow rate vs. Δp_1 the flow rate is 1.28 m³/min when Δp_1 = 6.0 in. H_2O. What is the new flow rate Q_{new} when T_{new} = 10°C and P_{new} = 770 mmHg?

29


SOLUTION:

$$Q_{new} = Q_{cal}\sqrt{\frac{T_{new} P_{cal}}{T_{cal} P_{new}}}$$

Q_{cal} = 1.28 m³/min @ Δp_1 = 6.0 in. H_2O

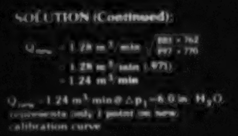
T_{new} = 10°C + 273 = 283 K

P_{new} = 770 mmHg

T_{cal} = 24°C + 273 = 297 K

P_{cal} = 762 mmHg

30a


SOLUTION (Continued):

$$Q_{new} = 1.28\ m^3/min\sqrt{\frac{283 \times 762}{297 \times 770}}$$

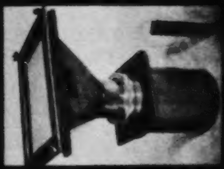
$= 1.28\ m^3/min\ (.971)$

$= 1.24\ m^3/min$

Q_{new} = 1.24 m³/min @ Δp_1 = 6.0 in. H_2O represents only 1 point on new calibration curve

30b

31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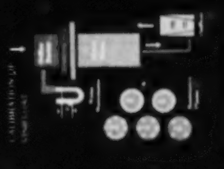
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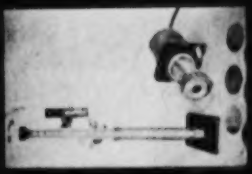
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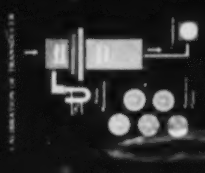

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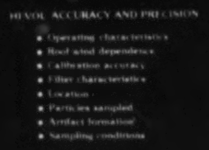
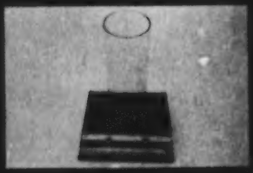

HI-VOL ACCURACY AND PRECISION
- Operating characteristics
- Roof wind dependence
- Calibration accuracy
- Filter characteristics
- Location
- Particles sampled
- Artifact formation
- Sampling conditions

40

41

INSERT EMULSION SIDE DOWN

11/79 435 LESSON 4 8



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LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: GENERATION OF TEST ATMOSPHERES

COURSE: 435 - Lesson #5
LESSON TIME: 1 hr. 15 min.
PREPARED BY: Northrop Services, Inc. **DATE:** 2/13/79

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

LESSON GOAL: To understand the basic methods for generating and analyzing the controlled atmospheres of gaseous pollutants that are used to calibrate or examine certain parameters of gaseous sampling and analysis methods.

LECTURE OBJECTIVES:

The student will be able to:

(1) identify the stability problems associated with low level cylinder gases -- specifically, SO_2 NO_2 and CO.

(2) Given the appropriate data, perform calculations necessary to determine the concentrations of gases produced by permeation systems and dilution systems.

(3) Outline at least two methods for actually metering diluent gas into a static or dynamic systems.

(4) Recognize and identify the adsorbents and apparatus necessary to produce zero air.

(5) Define NBS traceability in terms of Standard Reference Materials and non-NBS standards.

(6) Describe the construction and use of permeation systems.

SUPPORT MATERIALS AND EQUIPMENT:

Carousel projector and slides

Overhead projector or blackboard not required but convenient to have available.

SELECTED REFERENCES

1. Student Course Manual

2. "Gases: C. Static Calibration Techniques and D. Dynamic Calibration Method," in Instrumentation for Environmental Monitoring- Air, pp. 13-28, Published by Lawrence Berkeley Laboratories, Feb., 1976.

3. Nelson, G. O., *Controlled Test Atmospheres*, Chapter 4 - "Static Systems for Producing Gas Mixtures," pp. 59-94, and Chapter 5, "Dynamic Systems for Producing Gas Mixtures," pp. 95-160, Ann Arbor Science Publishers, 1971.

4. Bennett, Berne I., "Stability Evaluation of Ambient Concentrations of Sulfur Dioxide, Nitric Oxide, and Nitrogen Dioxide Contained in Compressed Gas Cylinders", EPA 600/4-79-006 (Feb, 1979) Quality Assurance Branch, Environmental Monitoring Systems Laboratory, Research Triangle Park, NC.

5. Kebbekus, E., and Scornavacca, F., "Factors in the Selection of Calibration Gas Standards", Am. Lab., July 1977.

6. "Traceability Protocol for Establishing True Concentration of Gases Used for Calibration and Audits of Continuous Source Emission Monitors" (Protocol No. 1), Environmental Monitoring Systems Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC.

7. "Traceability Protocol for Establishing True Concentrations of Gases Used for Calibration and Audits of Air Pollution Analyzers" (Protocol No. 2, June 1978), Environmental Monitoring Systems Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC.

8. Reckner, L. R., "Development of Technical Specification for Standard Gas - Diluent Mixtures for Use in Measurement of Mobile Source Emissions" U.S. Environmental Protection Agency, EPA-650/4-74-020.

9. Saltzman, B. E., et al, "Performance of Permeation Tubes as Standard Gas Sources", Anal. Chem. 5, 1121-28, (1971).

10. Singh, H. B., et al, "Generation of Accurate Halocarbon Primary Standards with Permeation Tubes" Environmental Science and Technology, 11, 511-513 (1977)

11. Hughes, E. E., et al, "Performance of a Nitrogen Dioxide Permeation Device", Anal. Chem. 49, 1824-29, (1977).

12. Pellizzari, E.D., "The Measurement of Carcinogenic Vapors in Ambient Atmospheres", Section 6, "Permeation System for Synthesizing Air/Organic Vapor Mixture for Calibrating Instruments." U.S. Environmental Protection Agency, EPA-600/7-77-055.

13. Mage, D. T., "Urban Diffusion Simulation Model for Carbon Monoxide and the Need for Accurate Span Gas Analysis," J. Air Poll. Control Assoc., 23, p. 970, (1973)

AIR POLLUTION TRAINING INSTITUTE

CONTENT OUTLINE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Course 435 - Lesson #5
Lecture Title: GENERATION OF TEST ATMOSPHERES

Page 1 *of* 8

NOTES

Review Lesson Objectives with the students.

I. INTRODUCTION

Test atmospheres are generated to provide calibration standards for air monitoring instrumentation. A working knowledge of preparation methods, stability, and availability of gas standards is essential since this is probably the greatest source of error in gas concentration measurement.

The problem with generating test atmospheres for the calibration of ambient instruments is particularly difficult because low levels (sub ppm range) of pollutant are required. There are numerous ways to generate these levels, but the following are in common use:

Mention the NAAQS levels for SO_2, O_3, NO_2, etc to illustrate the low-levels - measured.

A. Dynamic Systems - continuous generation of atmospheres

L5-1

(1) Dilute concentrated cylinder gas (e. g. concentrated cylinder gas followed by a series of dilutions)

(2) Permeation Systems
(3) Ozone generated by exciting O_2 with Hg vapor lamp

B. Static Systems - bag samples

Only mentioned.

Which system is the most accurate for generating the standard is dependent on the pollutant.

II. Pressurized Gas Cylinders and the stability of Ambient Concentrations of Sulfur Dioxide, Nitric Oxide, and Nitrogen Dioxide contained in compressed gas cylinders.

A. Three basic types of materials used to contain compressed gases

L5-2

(1) Steel cylinders
(2) Aluminum cylinders
(3) Treated cylinders

B. Factors affecting the stability of gas standards in pressurized cylinders:

L5-3

(1) contamination
(2) reaction
(3) absorption
(4) adsorption

In addition to the criteria gaseous pollutants (NO_2, SO_2, CO and HC), industries and agencies are being required (e. g. by the Toxic Substances Control Act, FDA, OSHA, etc) to analyze for such compounds as vinyl chloride, ammonia, hydrogen sulfide, and a variety of solvent vapors. The difficulties in preparing trace level concentrations of these compounds remain contamination, reaction, absorption, and adsorption in addition to the method of preparation. We will, at this point, confine our discussion to criteria air pollutant gases.

C. Stability of Criteria Gases

L5-4
A description of the stability of the gaseous criteria pollutants will be emphasized since students will be most concerned with these calibration gases

1. Sulfur Dioxide

Sulfur dioxide is a highly reactive gas which has been found to be unstable at low concentrations (e. g. 100 ppm and lower). The instability is due to:

1. reactions with moisture
2. reactions with other trace gas impurities
3. reactions with the cylinder wall

L5-5

L5-6
*A stable gas mixture is defined as one in which the concentration of the trace gas changes no more than 3% from its original concentration over a 3-month period.

2. Nitrogen Dioxide

Like sulfur dioxide, nitrogen dioxide is a highly reactive and corrosive gas which has been found to be extremely unstable at low concentrations (e. g. 100 ppm and lower) for the same reasons.

Because of their instability in cylinders and the availability of stable permeation devices (SO_2 and NO_2) and dilution systems -- Permeation systems are the best methods for calibrating NO-NO_2-NO_x or SO_2 ambient analyzers.

Point out that permeation devices and the associated dilution systems will be discussed in detail later in this lecture.

3. Carbon Monoxide L5-7

The most common cylinder material for CO gas standards has been steel alloys. Stable mixtures of 10-500 ppm CO in nitrogen are available and may be stored at temperatures from -10° to 100°F without loss of stability in manganese steel cylinders. The selection of the cylinder material is important since CO was found to be unstable in chrome-moly and other ((treated) cylinders. The manganese steel cylinders are heavier (~ 20 pounds) which adds higher transportation cost - but provides a stable calibration gas mixture. It is believed that L5-8 unstable CO mixtures are primarily the result of the formation of iron carbonyls on the cylinder walls.

4. Nitric Oxide L5-9

Although NO is not a criteria pollutant, it is used in the calibration of $NO-NO_2-NO_x$ ambient analyzers and is, therefore, an important gas standard. 100 ppm cylinders of NO are stable in steel or aluminum cylinders and are commercially available.

Low level concentrations of both CO and NO can be easily generated by dilution of cylinder gas (e. g. 100 ppm to 10 ppm by a ten-fold dilution)

5. Hydrocarbons L5-10

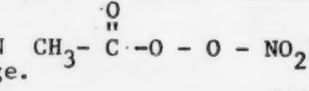
The stability of hydrocarbons in compressed gas cylinders is dependent on the particular hydrocarbon for which a standard is needed. In general, the more reactive hydrocarbons are the least stable . . .

relatively less stable:	aromatics, oxygenated or halogenated hydrocarbons, etc.
relatively more stable:	propane, butane, hexane, methane (methane most commonly used in Air Pollution monitoring)

L5-11

6. Ozone and other Photochemical Oxidants L5-12

Because Ozone (O_3) is unstable in any material for even short lengths of time, the standard must be generated and measured in-situ by an absolute technique L5-13 (e. g. UV photometry). Methods for preparing standards for other photochemical oxidants such as the acyl nitrates



$CH_3-\overset{\overset{O}{\|}}{C}-O-O-NO_2$

(e.g. PAN $CH_3-\overset{\overset{O}{\|}}{C}-O-O-NO_2$) are still in the development stage.

III. Permeation Systems

L5-14a

L5-14b

Permeation tubes were originally described by O'Keeffe and Ortman in 1966 as convenient calibration sources. They consist of liquified gases such as sulfur dioxide, nitrogen dioxide, hydrocarbons, halocarbons, or hydrogen sulfide in an inert plastic tubing such as FEP Teflon (fluorinated ethylene propylene copolymer) or TFE Teflon (tetra-fluoroethylene polymer) which permeate through the tubing walls at constant rates for long periods. The permeation rate is extremely temperature sensitive; a change of 0.1°C can alter the permeation rate on the order of 4%. The determination of permeation rate or calibration of the tube is a straight forward gravimetric procedure:

(Note: 2 major types of permeation devices exist, most common is as in L5-14a. Other is primarily for NO_2 as in slide L5-14b)

$$\text{rate } (\mu g/\text{min}) = \frac{\text{mass}_{\text{init}} - \text{mass}_{\text{final}}}{\text{time}}$$

L5-15

Tubes which are purchased from NBS have certified permeation rates at various temperatures.

Explain NBS calibration set-up.

They can be calibrated by a set-up in which the weight loss of the tube is recorded directly. This avoids the possible weigh errors due to the adsorption or absorption of water vapor. The slope of the recorder trace is the permeation rate.

L5-16

L5-17

In toto, a permeation system would consist of a permeation tube which is maintained at a constant temperature (usually by a water bath or constant temperature oven) and flow of clean dry air across the tube (ranges from 10-500 cc/min. depending on the permeation rate). This air stream is further diluted with zero air in a mixing bulb. The flow of the dilution air or the flow across the permeation tube may be varied to give different concentrations of calibration gas.

L5-18

L5-19

L5-20

The concentration of the calibration gas in ppm

Explain these components on a portable system

$$C = \frac{(PR)\ (MV)}{(Q_{total})\ (MW)}$$

Where: C = concentration in ppm

PR = permeation rate in μg/min

MV = molar volume in μℓ/μmole

Q_{total} = total flow rate (flow rate across the permeation tube + the diluent gas flowrate)ℓ/min

MW = molecular weight in μg/μmole

This equation is derived by taking the PR and dividing by the flow rate and then converting the μg to μmoles and from μmoles to μℓ. Make sure students understand this is a variation of the calculation they performed in Lecture #2 and homework exercises

As can be seen from the equation, the accuracy of the flowrate measurement is as important as the permeation rate.

PERMEATION SYSTEM CALCULATIONS

Problem 1.

L5-21

Given: Permeation rate = 1.75 μg SO_2/min @ 25°C
Permeation Temp = 25°C
dilution flow:

dilution air = 6350 SCCM (ml/min)
carrier across permeation tube = 50 SCCM (ml/min)

What is the concentration of the SO_2 atmosphere generated?

Solution: The molar volume @ 25°C, 1ATM = 24.46 μℓ/μmole
Molecular weight of SO_2 = 64 μg/μmole

$$C_{SO_2} = \frac{(PR)\ (MV)}{(Q_{total})\ (MW)}$$

$$Q_{total} = 50 \text{ SCCM (ml/min)} + 6350 \text{ SCCM (ml/min)}$$
$$= 6400 \text{ SCCM (ml/min)} = 6.4 \text{ ℓ/min.}$$

L5-22

$$C_{SO_2} = \frac{(1.75\ \mu g/min.)\ (24.46\ \mu\ell/\mu mole)}{(6.4\ \ell/min.)\ \ (64 \mu g/\mu mole)}$$

$$C_{SO_2} = 0.105\ \mu\ell/\ell = .105 \text{ ppm } SO_2$$

Problem 2.

An SO_2 continuous analyzer has been calibrated with an NBS permeation tube and a permeation system. A SO_2 tube was purchased commercially and it is desired to determine the permeation rate using the calibrated SO_2 analyzer. The flow across the permeation tube is 100 cc/min or ml/min and the dilution flow is 1 ℓ/min. The analyzer reads .250 ppm, what is the permeation rate?

Use blackboard to run through this problem

Solution: $$PR = \frac{(Cppm)\,(MW)\,(Q_{total})}{MV} \quad @\ 25°C \text{ and } 760 \text{ mmHg}$$

$$PR = \frac{(.250)\,(64)\,(1.1)}{(24.46)}$$
$$= .720 \mu g/min$$

This is one of the steps for NBS traceability of commercial permeation tubes: Traceability to Standard Reference Materials is important in monitoring for a variety of reasons. The traceability process is basically a sequence of prescribed analytical procedures that relate a SRM (Standard Reference Material) to Non-NBS standards.

L5-23

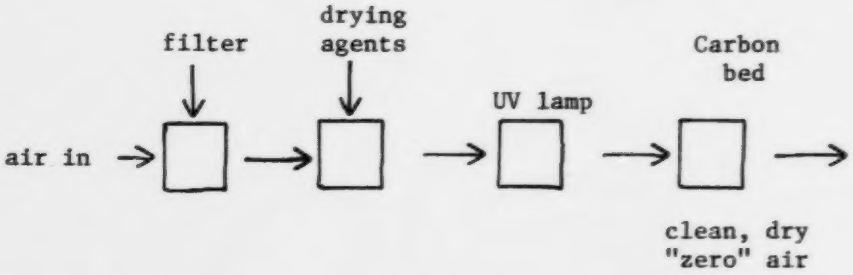
IV. Preparation of (Zero) Diluent Air

In order to dilute gas standards from cylinders or gas streams coming from permeation systems, clean, (e.g. free of the pollutant being measured and/or any possible interfering species) dry "zero" air must be readily available. Zero air can be purchased or prepared in-situ. In general, this consists of passing the air to be cleaned through:

1. filter to remove heavy oils and particulates
2. Molecular sieves and/or other drying agents such as silica, perma-pure dryer, etc.
3. UV lamp used to convert NO to NO_2 which is readily adsorbed by carbon.
4. Carbon bed to remove NO_2 and organics

Having discussed method of introducing the diluent gas, a method of preparation of the "zero gas" or diluent air will be discussed.

L5-24



L5-25

Picture of actual drying set-up.

Explain components in actual set-up.

V. Methods for Dilution of Concentrated Gas Streams

Once a stable, relatively high concentration gas stream has been generated by a permeation tube or cylinder gas, it is necessary to accurately introduce a known volume of diluent air (usually zero air) into a mixing chamber in order to generate a specified concentration of pollutant. Generally, this can be done by a single dilution or a series of dilutions. Dilution systems consist of a flow control mechanism and method to measure the flow - for example:

L5-26

- Flow control valves or flow metering valves and a primary standard such as a soap bubble meter (and timer) or secondary standards (rotameter or mass flow meter) to measure the flow rate.

L5-27

Explain the operation of a fine metering valve

.. adjusting the stem of the valve controls the opening of the orifice and thus the flow.

L5-28

Uses

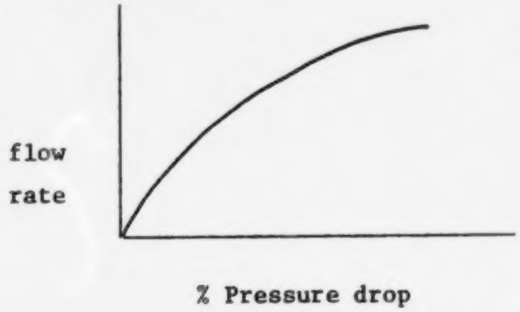
It is used frequently for carrier gas control on gas chromatographs and air flow control in many atmospheric analyzers and sampling systems.

Vary pressure drop across an orifice and relate the pressure drop to the flow rate

Slide L5-29
Students will be using this method in the laboratory.

Actual instrument using % pressure drop gauge as flow rate control.

e.g.



L5-29a
actual instrument

Calculations: Basic Equation for dilution problems

$$C_1V_1 = C_2V_2$$

or

$$C_1Q_1 = C_2Q_2$$

L5-30

Dilution Problem:

Given:
tank conc: 94.8 μℓ/ℓ
flow rate from tank: 4.6 ml/min.
flow rate of dilution gas: 2250 ml/min.

L5-31

What is the concentration of diluted gas?

$$C_2 = \frac{C_1 \, Q_1}{Q_2}$$ L5-32

C_1 = tank concentration = 94.8 μℓ/ℓ

Q_1 = tank flow rate = 4.6 mℓ/min

Q_2 = tank flow rate + dilution flow rate
= 4.6 mℓ/min + 2250 mℓ/min = 2254.6 mℓ/min

$$C_2 = \frac{(94.8\ \mu\ell/\ell)\ (4.6\ \text{ml/min})}{2254.6\ \text{ml/min}}$$ L5-33

C_2 = 0.193 μℓ/ℓ

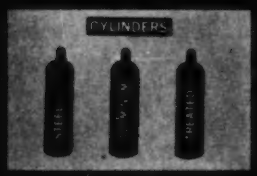
C_2 = 0.193 ppm

INSERT EMULSION SIDE DOWN

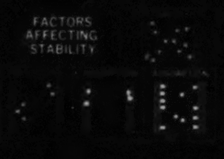
11/79 435 LESSON 5 9

TEST ATMOSPHERE GENERATION
BAG
ppm NO

1


CYLINDERS
STEEL
HEATED

2

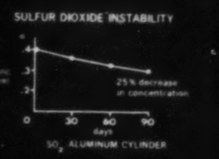

FACTORS AFFECTING STABILITY

3

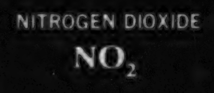
SULFUR DIOXIDE

SO_2

4



5


NITROGEN DIOXIDE

NO_2

6

CARBON MONOXIDE

CO

7

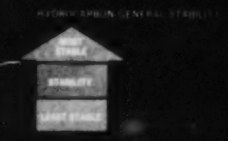
8

NITRIC OXIDE

9

HYDROCARBONS

10

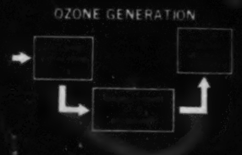

HYDROCARBON GENERAL STABILITY
MOST STABLE
STABILITY
LEAST STABLE

11

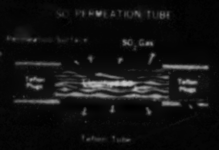
OZONE

O_3

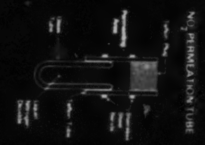
12


OZONE GENERATION

13


SO2 PERMEATION TUBE
Permeation Surface
SO2 Gas
Teflon Plugs
Teflon Plugs
Teflon Tube

14a


NO2 PERMEATION TUBE

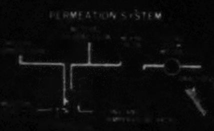
14b

PERMEATION RATE $\left(\frac{\mu g}{min}\right) = \frac{\text{initial mass} - \text{final mass}}{\text{time}}$

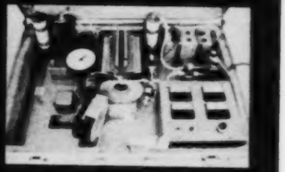
15

16

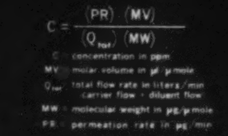
17


PERMEATION SYSTEM

18



19


$$C = \frac{(PR)\ (MV)}{(Q_{tot})\ (MW)}$$

C = concentration in ppm

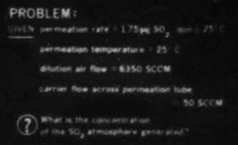
MV = molar volume in µl/µmole

Q_{tot} = total flow rate in liters/min = carrier flow + diluent flow

MW = molecular weight in µg/µmole

PR = permeation rate in µg/min

20


PROBLEM:

GIVEN permeation rate = 1.75 µg SO_2/min @ 25°C

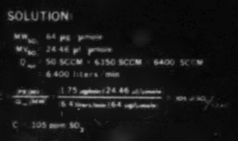
permeation temperature = 25°C

dilution air flow = 6350 SCCM

carrier flow across permeation tube = 50 SCCM

? What is the concentration of the SO_2 atmosphere generated?

21


SOLUTION:

MW_{SO_2} = 64 µg/µmole

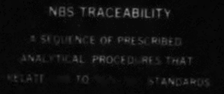
MV_{SO_2} = 24.46 µl/µmole

Q_{tot} = 50 SCCM + 6350 SCCM = 6400 SCCM = 6.400 liters/min

$$C = \frac{(PR)(MV)}{(Q_{tot})(MW)} = \frac{(1.75\ \mu g/min)(24.46\ \mu l/\mu mole)}{(6.4\ liters/min)(64\ \mu g/\mu mole)}$$

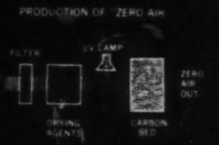
C = .105 ppm SO_2

22

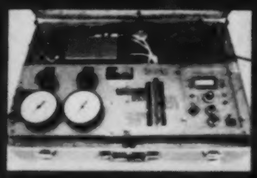

NBS TRACEABILITY

A SEQUENCE OF PRESCRIBED ANALYTICAL PROCEDURES THAT RELATE [illegible] TO [illegible] STANDARDS

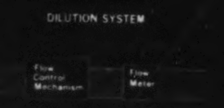
23


PRODUCTION OF "ZERO AIR"
FILTER
UV LAMP
AIR IN
DRYING AGENTS
CARBON BED
ZERO AIR OUT

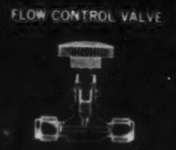
24



25


DILUTION SYSTEM
Flow Control Mechanism
Flow Meter

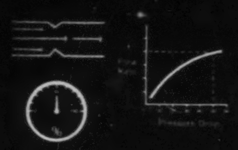
26


FLOW CONTROL VALVE

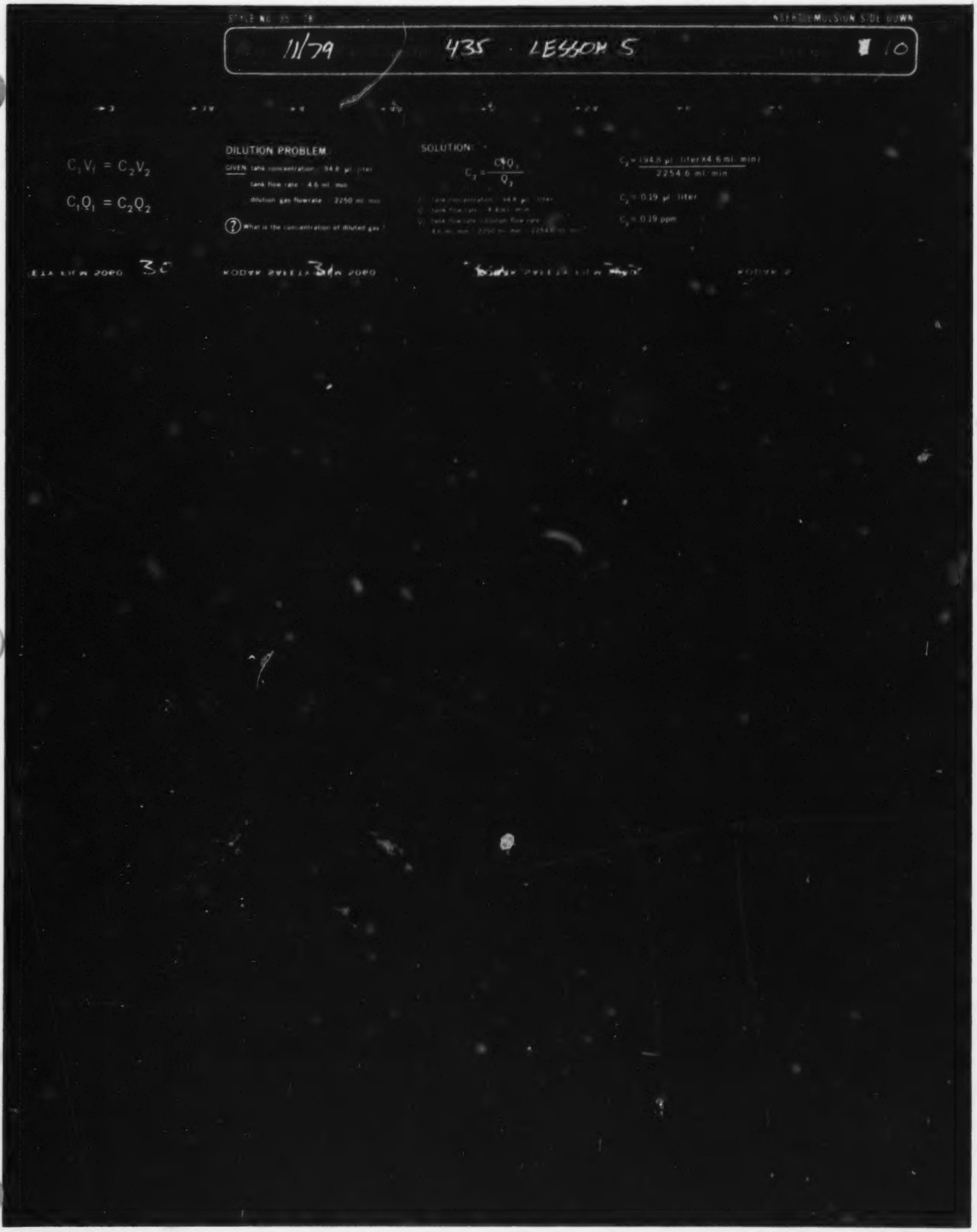
27

NEEDLE VALVE

28


Flow Rate
Pressure Drop

29



STYLE NO. 35

NOTCH EMULSION SIDE DOWN

11/79 435 LESSON 5 10

$$C_1V_1 = C_2V_2$$

$$C_1Q_1 = C_2Q_2$$

DILUTION PROBLEM

GIVEN: tank concentration = 94.8 µl/liter

tank flow rate = 4.6 ml/min

dilution gas flowrate = 2250 ml/min

② What is the concentration of diluted gas?

SOLUTION:

$$C_2 = \frac{C_1Q_1}{Q_2}$$

C_1 = tank concentration = 94.8 µl/liter

Q_1 = tank flow rate = 4.6 ml/min

Q_2 = tank flow rate + dilution flow rate

4.6 ml/min + 2250 ml/min = 2254.6 ml/min

$$C_2 = \frac{(94.8\ \mu l/liter)(4.6\ ml/min)}{2254.6\ ml/min}$$

C_2 = 0.19 µl/liter

C_2 = 0.19 ppm

30

31

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: Air Movers

COURSE: 435 - Lesson #6
LESSON TIME: 30 Min.
PREPARED BY: Northrop Services, Inc.
DATE 2/13/79

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

6

LESSON GOAL: To introduce the types and principles of operation for various pumps used in atmospheric sampling.

LESSON OBJECTIVES:

The student will be able to:

1. List six considerations in selecting an air mover for a given sampling situation.
2. Differentiate between positive displacement and centrifugal pumps.
3. Describe the operation of the following air movers
    a. Piston pump
    b. Diaphragm pump
    c. Vane pumps
    d. Ejectors
    e. Liquid displacement

SUPPORT MATERIALS AND EQUIPMENT:

1. Objective Handout
2. Carousel Projector and Slides
3. Overhead or blackboard

SPECIAL INSTRUCTIONS:

It will aid the instructional process to have examples of the various pumps in the classroom for demonstration.

SELECTED REFERENCES:

1. Furtado, V. C. and Harris, W. B., "Air Movers," Air Sampling Instruments. American Conference of Governmental Industrial Hygienists. Fourth Edition, 1972.

2. Kristal, F. A., and Annett, F.A., Pumps. McGraw-Hill Book Company, Inc., New York, 1953, Ch. 1.

3. Mitchell, C. B., "Which Pump and Why?" Chapter 4 of Fluid Flow in Practice. Reinhold Publishing Corporation, New York, 1956.

CONTENT OUTLINE

Course: 435 - Lesson #6
Lecture Title: AIR MOVERS

Page 1 *of* 3

	NOTES
I. INTRODUCTION	
An air mover is what the term indicates - a pump, mechanism, or device for moving air.	L6-1
It creates an air flow through the sampling system in order to collect contaminants for analysis.	
The air mover is an integral part of the atmospheric sampling system.	Slide showing Air Mover position in a sample train
II. CRITERIA FOR SELECTION OF AN AIR MOVER	
1. Pollutant concentration and sampling time	L6-2a
2. Sampling rate required. Must sample at a sufficient rate and time to collect the minimum quantity of contaminant required for proper analysis.	L6-2b
Example: 10μg of contaminant required for analysis. Air Mover samples at 1 m^3/hr. Air contains an average 1 μg/m^3 contaminant. 10 hour sample time would therefore be necessary.	Show this example on overhead or blackboard
Important in impingement systems where chemical reactions times are involved, particulate sampling involving inertia.	
3. Physical and Chemical Nature of air to be sampled. Air Mover must be resistant to abrasives, explosive gas mixtures, corrosive gases, heat, cold, etc. common to sampling site.	L6-2c
4. Portability of Air Movers If Air Mover isn't in a permanent facility it must be capable of easy relocation i.e., light, compact. External power requirements - electricity.	L6-2d
5. Air Mover Noise Important in closed work environment due to OSHA standards, residential area uses.	Slide L6-2e
6. Air Mover Maintenance Should be serviceable in the field, parts should be easily accessible, shouldn't be time consuming, parts must be relatively inexpensive and easily purchased.	L6-2f
7. Resistance - Air Mover must overcome the resistance to air flow caused by sampling device.	L6-2g

8. Constant Flow Rate - Important in knowing the true amount of air sampled so as to calculate concentration of contaminant per unit volume of air. L6-2h

III. TYPES OF AIR MOVERS

A. Pumps L6-3

1. Major device employed as an Air Mover

2. Two Types - Postive displacement pump, and centrifugal pump

a. Positive Displacement Pump L6-4

Characterized by a linear relationship between suction pressure and pump capacity (as pump flow rate increases, pressure drop across the pump increases)

Operates by principle of air being displaced (moved) by the movement of movable, tight fitting parts--pistons, gears, lobes, etc. Two sub categories of positive displacement pumps - Reciprocating (Piston, Plunger, Diaphragm) and Rotary (gear, lobe, vane)

b. Centrifugal Pumps L6-5

Δp to ΔQ relationship is not linear. Operate by air being forced outward by centrifugal force from an impeller. Movement of impeller creates a low pressure at its center which draws air in. The air is moved around by the impeller in a volute casing (snail shell) which decreases velocity but increases pressure. A common hair dryer and Hi-Vol blower are good examples.

c. Description of Selected Pumps L6-6

1. Piston pump: air is drawn in through the suction valve and displaced through the discharge valve.

2. Diaphragm pump: A pulsating rubber diaphragm moves relatively large volumes of air

3. Carbon vane: Of the rotary type. Are positive displacement pumps in which the vanes or impellers move rotationally requiring no suction or discharge valving.

CONTENT OUTLINE

AIR POLLUTION TRAINING INSTITUTE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Course: 435 - Lesson #6
Lecture Title: AIR MOVERS

Page 3 *of* 3

NOTES

B. Ejectors (aspirators) — L6- 7

Operate by jet principle - high velocity driving force passed through a suction chamber. High velocity stream result in lower pressure thereby drawing in ambient air for sampling...uses Bernoulli's principle.

High velocity stream supplied by water, steam, compressed air, CO_2, etc.

Advantages - No electrical power source required

Disadvantages -Time limit on driving force, low sampling rates

C. Liquid Displacement — L6-8

Operate by simple displacement of liquid in a closed container by air upon release of the liquid; only used in grab sampling.

D. Evacuated Flask — L6-9

The flask is evacuated by means of a vacuum pump and is then sealed. In the field, a valve is opened and air being sampled is taken into the flask. — L6-10

END OF CLASS FOR THE DAY

INSERT EMULSION SIDE DOWN

11/79 435 LESSON 6 11

AIR MOVERS ?
Devices for Moving Air

1

2a

2b

2c

CRITERIA FOR SELECTION OF AN AIR MOVER

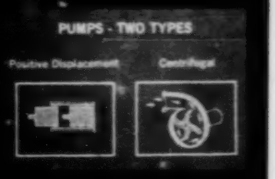
2d

2e

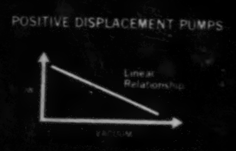
2f

2g

2h


PUMPS - TWO TYPES
Positive Displacement
Centrifugal

3



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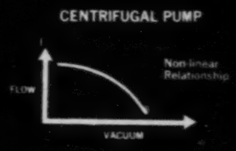
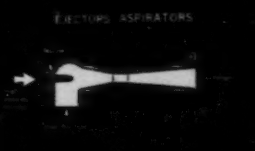


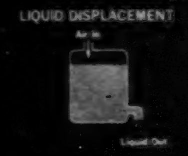
5

TYPICAL PUMPS

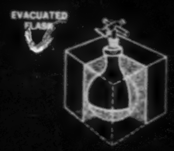
6


EJECTORS, ASPIRATORS

7


LIQUID DISPLACEMENT
Air In
Liquid Out

8


EVACUATED FLASK

9

That's All Folks!!

10

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: PROBLEM SET I

COURSE: 435 - Lesson #7
LESSON TIME: 45 min.
PREPARED BY: Northrop Services, Inc. DATE: 2/1/79

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

LESSON GOAL: To review problem Set I with the students.

LESSON OBJECTIVES:

At the conclusion of this session, the student should be able to:

-- Work the exercises in problem Set I.

SUPPORT MATERIALS:

Overhead Projector or blackboard

Exercise Manual (Lab Manual)

SPECIAL INSTRUCTIONS:

Students are assigned this problem set as homework at the end of the first day of the course. In the morning of the second day, the problems are reviewed in class.

Students have difficulty with these calculations. They should, therefore, be explained thoroughly. Students occasionally have problems with dimensional analysis, therefore, include the units in each problem.

435 - Atmospheric Sampling

Problem Set I

EXAMPLE PROBLEM

Problem:

An atmosphere was analyzed for NO_2 using the TGS-ANSA equivalent method. In this method the sample air is drawn through a known volume of absorbing reagent where the NO_2 is quantitatively collected over a known time period. The concentration of NO_2 in the absorbing reagent is determined by a colorimetric analytical procedure. The following data was collected:

Sampling Conditions:	25°C, 760 mmHg
Sampling Flowrate:	200 mℓ/min
Sampling Time:	24 hrs
NO_2 concentration found in the Absorbing Reagent:	3.0 μg/mℓ
Volume of Absorbing Reagent:	50 mℓ
MW of NO_2:	46 g/mole
Collection Efficiency:	93%

What is the NO_2 concentration in the atmosphere in $\mu g/m^3$ and ppm.

Solution:

(1) Determine the mass of NO_2 collected

$$\begin{array}{l}\text{Mass of } NO_2\\ \text{collected}\end{array} = \left(\begin{array}{c}\text{concentration } NO_2 \text{ in}\\ \text{Absorbing Reagent}\end{array}\right)\left(\begin{array}{c}\text{Volume of}\\ \text{Absorbing}\\ \text{Reagent}\end{array}\right)$$

$$= \left(3.0\ \frac{\mu g NO_2}{m\ell}\right)\left(50\ m\ell\right) = 150\ \mu g NO_2$$

(2) Only 93% of the NO_2 was collected; therefore, a correction must be made to obtain the total amount of NO_2 (100%) that should have been collected:

$$\left(150\ \mu gNO_2\right)\left(\frac{1}{0.93}\right) = 161\ \mu gNO_2$$

(3) Determine the volume of air sampled

Volume of air sampled = (flowrate) (time)

$$= \left(\frac{200 m\ell}{min}\right)\left(24\ hrs\right)\left(\frac{60 min}{hr}\right) = 2.88 x 10^5 m\ell = 288\ \ell$$

(4) Calculate concentration

$$\frac{\mu g}{m^3} = \frac{\mu gNO_2}{\text{vol. of air}} = \left(\frac{161\ \mu gNO_2}{288\ \ell}\right)\left(\frac{1000\ \ell}{m^3}\right) = 559 \mu g/m^3$$

(5) To obtain ppm convert $\mu g/m^3$ to ppm

$$ppm = \frac{\mu \ell NO_2}{\ell\ air}$$

$$ppm = \left(\frac{559 \mu gNO_2}{m^3}\right)\left(\frac{1 m^3}{1000\ \ell}\right)\left(\frac{1\ \mu\ moleNO_2}{46 \mu gNO_2}\right)\left(\frac{24.45 \mu \ell}{1\ \mu mole}\right)$$

$$= 0.297\ \mu\ell/\ell \text{ or}$$

$$0.297\ ppm$$

ATMOSPHERIC SAMPLING
COURSE 435

PROBLEM SET 1

(1) Standard conditions for temperature and pressure are $0^\circ C$ and 760 mm Hg for most chemistry applications. The molar volume ($\overline{V}$) of an ideal gas at $0^\circ C$ and 760 mm Hg is 22.4 liters/mole. Standard conditions for reporting air pollution data is $25^\circ C$ and 760 mm Hg. What is the molar volume ($\overline{V}$) of an ideal gas at $25^\circ C$ and 760 mmHg?

(2) Convert 3200 $\mu g\ SO_2/m^3$ to ppm SO_2 ($\mu \ell SO_2/\ell$) if the sampling conditions were EPA standard conditions, $25^\circ C$ and 760 mm Hg, (MW of SO_2=64g/mole).

(3) Thirty (30.0) liters of air were passed through 10 ml of absorbing solution. Chemical analysis of the solution gave a result of 0.3 micrograms of SO_2 per ml of absorbing reagent. Assuming reference conditions of 760 mm Hg & $25^\circ C$ and 100% collection efficiency, what was the concentration of SO_2 in the atmosphere, expressed in $\mu \ell/\ell$ (ppm)? (MW of SO_2 = 64g/mole).

(4) Calibration of an NDIR Carbon Monoxide (CO) instrument is sometimes done with static test atmospheres. Instruments are usually calibrated at 90% of full scale. A chemist wishing to calibrate the 50 ppm range of a CO monitor must add how many mℓ of 500 ppm CO to a 10 liter Tedlar bag to obtain a concentration of 45 ppm (90% of 50 ppm).

(5) Using the following data on a NO_2 permeation system, calculate the concentration of NO_2 expressed in ppm in the test gas stream.

Permeation rate: 1.65 µg/min @ 25.0°C

Permeation temperature: 25.0°C

Total flow rate: 3000 mℓ/min

Molecular weight NO_2: 46 g/mole

(6) The single dilution system shown is used to calibrate an NO-NO_2-NO_x instrument. If the flow from the 109ppm NO cylinder is 8.9 mℓ/min and the flow from the zero air cylinder is 1500 mℓ/min, what is the concentration of NO exiting the mixing chamber?

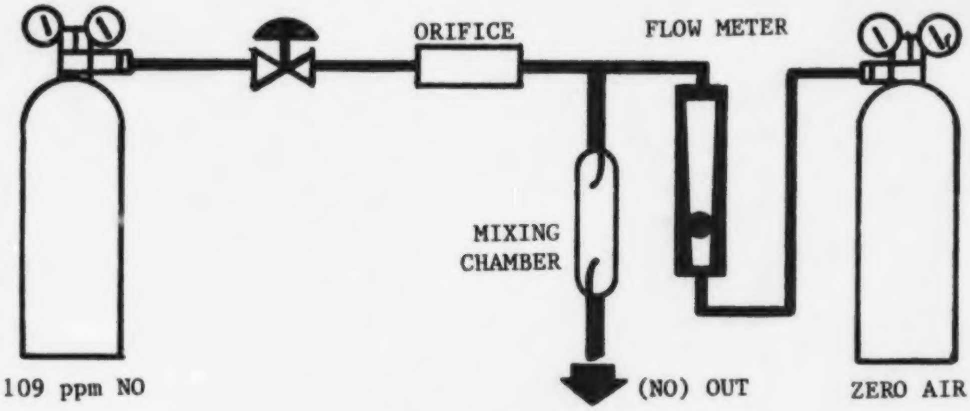


Figure 1. Single Dilution System

(7) A high volume sampler was run for one day from midnight to midnight. The initial flowrate was 55 cfm. The final flow was 53 cfm. The clean filter weighed 2.9845g. The filter weighed 2.9969g after sampling. What is the total suspended particulate (TSP) concentration in µg/m³?

(8) A moving bubble meter is used to calibrate a lowflow rotameter. The rotameter is placed before the bubble meter in the calibration train. The bubble meter volume is 100 mℓ. If the calibration conditions are 27.6°C and 756 mm Hg what percentage error will be made if the bubble meter volume is not corrected to dry conditions (tank air is used so the rotameter is measuring dry air)? The vapor pressure of water at 27.6°C is 27.696 mm Hg. HINT: Percent error is calculated by the following formula:

$$\% \text{ ERROR} = \left(\frac{\text{True Value} - \text{Measured Value}}{\text{True Value}}\right)(100)$$

SOLUTIONS TO PROBLEM SET I.

1.

$$\bar{V} = 22.4\ell\text{/mole}\left(\frac{298\ °\text{K}}{273\ °\text{K}}\right)$$

$$\bar{V} = 24.46\ell\text{/mole}$$

This problem can be worked using the ideal gas law: $V = \frac{nRT}{P}$, However, since the only parameter being changed is temperature and the volume at 0^{o}C and 760 mmHg is given (22.4ℓ) it is more convenient to use Charles' Law. Review this if necessary. This problem was also worked in class.

2.

$$\left(3200\ \mu\text{g SO}_2/\text{m}^3\right)\left(\frac{1\ \mu\text{mole}}{64\ \mu\text{g}}\right)\left(\frac{24.46\ \mu\ell}{1\ \mu\text{mole}}\right)\left(\frac{10^{-3}\ \text{m}^3}{1\ell}\right) =$$

1.22 µℓ/ℓ or 1.22 ppm

3.

Step 1: Determine total amount of SO_2 collected

$$\left(.3\ \mu\text{g/ml}\right)\left(10\ \text{ml}\right) = 3\ \mu\text{g}$$

Step 2: Determine concentration in µg/ℓ

$$3\ \mu\text{g}/30\ \ell = \frac{.1\ \mu\text{g}}{\ell}$$

Step 3: Convert µg/ℓ to µℓ/ℓ

$$\left(.1\ \mu\text{g}/_{\ell}\right)\left(\frac{1\ \mu\text{mole}}{64\ \mu\text{g}}\right)\left(\frac{24.46\mu\ell}{\mu\text{mole}}\right) = \frac{.038\ \mu\ell}{\ell}$$

Or .038 ppm

4.

$$(500\ \text{ppm})\ V_1 = (45\ \text{ppm})\ (10\ell)$$

$$V_1 = \frac{(45)\ (10\ell)}{(500)}$$

$$V_1 = 0.900\ \ell$$

$$V_1 = 900\ \text{ml}$$

5. $C = \frac{(PR)(MV)}{(Q_T)(MW)}$

$C = \frac{(1.65\ \mu g/min)\ (24.46\ \mu \ell/\mu mole)}{(3\ell/min)\ \ \ (46\ \mu g/\mu mole)}$

$C = .29\ \mu\ell/\ell$ or .29 ppm

6. $C_1Q_1 = C_2Q_2$

(109 ppm) (8.9 ml/min) = C_2 (1508.9 ml/min)

$Q_2 = Q_1$ + dilution air flow

$C_2 = \frac{(109\ ppm)\ (8.9\ ml/min)}{(1508.9\ ml/min)}$

$C_2 = .64$ ppm

Point out that all units cancel out except ppm.

7. TSP in $\frac{\mu g}{m^3} = \frac{(W_f - W_i)\ (10^6)}{(flow)\ (Time)}$

Where flow is in $\frac{m^3}{min}$,
weight is in grams,
and time is in min.

$$TSP = \frac{(2.9969g - 2.9845g)\left(10^6\ \frac{\mu g}{g}\right)}{\left(\frac{53 + 55\ cfm}{2}\right)\left(\frac{.02832m^3}{ft^3}\right)\ (24\ hrs)\ \left(\frac{60\ min}{hour}\right)}$$

$$= \frac{.0124}{2202.16} \times 10^6 = \frac{5.63\ \mu g}{m^3}$$

8.

$$V_{correct} = V_{original} \left(\frac{P_{atm} - P_{H_2O}}{P_{atm}}\right)$$

$$V = 100 \left(\frac{756.00 - 27.696}{756}\right)$$

$$V = 96.34 \text{ ml}$$

$$\% \text{ Error} = \left(\frac{\text{True Value - Measured Value}}{\text{True Value}}\right) (100)$$

True value = 96.34 ml

Measured value = 100 ml

$$\% \text{ Error} = \left(\frac{96.34 \text{ ml} - 100 \text{ ml}}{96.34 \text{ ml}}\right) \quad (100)$$

$$= -3.8\%$$

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: PRINCIPLES OF GASEOUS SAMPLING

COURSE: 435 - Lesson #8
LESSON TIME: 45 Min.
PREPARED BY: Northrop Services, Inc.
DATE: 2/1/79

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

LESSON GOAL:

To recognize and understand the principles and equipment that are used in sampling for gaseous pollutants.

LESSON OBJECTIVES: The student will be able to:

(1) Distinguish between the principles of grab and integrated gas sampling.

(2) Identify the characteristics of adsorption, absorption, and freezeout sampling.

(3) List at least two common materials used as adsorbents.

(4) List the type of samples most commonly collected by adsorption and freezeout sampling.

(5) Describe at least one type of analytical procedure for quantifying gaseous pollutants collected by adsorption.

(6) List at least two potential problems common to adsorbent collection and analysis of gases.

(7) List at least two factors affecting collection efficiency of an absorber.

(8) Distinguish the difference between physical and chemical absorption.

SUPPORT MATERIAL AND EQUIPMENT:

1. Objective Handout
2. Carousel Projector and Slides

SPECIAL INSTRUCTION:

Although the content of this lecture deals with numerous gaseous sampling methods, the specific details of methods for the criteria pollutants should be avoided since they are discussed in detail in the Reference Method Lecture (Lesson #12) on day 4. The lecture concerns principles and basic methods for collecting and analyzing gaseous pollutants. Each principle or technique should be illustrated with current examples as well as the limitations and problems associated with each technique. Avoid generalities, yet do not over emphasize one subject or technique. For example, some of the techniques currently being used in conjunction with adsorbent cartridges (e.g. GC/MS) or in gas phase analysis (e.g. a continuous pulsed fluoresence H_2S monitor, monitors for vinyl chloride using chemiluminescence, etc.) are somewhat esoteric and beyond the scope of a 45 min. introductory lecture.

SELECTED REFERENCES:

U.S. Department of Health, Education and Welfare, "NIOSH Manual of Analytical Methods" NIOSH 75-121.

U.S. Department of Health, Education and Welfare, "NIOSH Manual of Analytical Methods" Vol. 3, NIOSH/77-157-C.

Dunlap, K.L., Sandridge, R.L., Keller, J., "Determination of Isocyanates in Working Atmospheres by High Speed Liquid Chromatography", Anal. Chem. 47, 497-499 (1976).

"Polynuclear Aromatic Hydrocarbons: Trace Level Determination in Workplace Air" Waters Associates, Application Note # H71, Waters Associates, Inc., Maple Street, Milford, MA (1976)

Pellizzari, E.D., "The Measurement of Carcinogenic Vapors in Ambient Atmospheres" EPA-600/7-77-055, June 1977.

Black, M.S., Herbst, R.P., Hichcock, D.R., "Solid Adsorbent Preconcentration and Gas Chromatographic Analysis of Sulfur Gases" Anal. Chem., 50, 848 (1978)

Cheremisinoff, P.N., Morresi, A.C., Air Pollution Sampling and Analysis Deskbook, Chapter 6, "Ambient Sampling", Ann Arbor Sciences Publishers, Inc., Ann Arbor, Michigan, 1978.

Madjar-Vidal, C., Gonnord, M.F., Benchah, F., Guiochon,G. "Performances of Various Adsorbents for the Trapping and Analysis of Organohalogenated Air Pollutants by Gas Chromatography" J. Chromatogr. Sci., 16, 190 (1978).

Lewis, R.G., Brown, A.R., Jackson, M.D., "Evaluation of Polyurethane Foam for Sampling of Pesticides, Polychlorinated Biphenyls and Polychlorinated Napthalenes in Ambient Air", Anal. Chem., 49, 1668 (1977)

Fine, D. H., Et al, "Nitrosodimethylamine in Air", Bulletin of Environmental Contamination and Toxicology, 15, 6, 739 (1976).

* These references are very specific for different airborne pollutants - however, they illustrate most of the topics discussed in this lecture.

CONTENT OUTLINE

Course: 435 - Lesson #8
Lecture Title: PRINCIPLES OF GASEOUS SAMPLING

NOTES

I. REVIEW LESSON OBJECTIVES WITH THE STUDENTS.

II. In sampling for gaseous pollutants, there are four principles or methods that are most often used: L8-1

1. Absorption
2. Adsorption
3. Condensation or freezeout techniques
4. Grab sampling

These are the general methods that will be covered in this lecture.

A. Absorption

The removal from a gas stream of a gaseous constituent by a solid or liquid matrix in which the molecules of the gas actually penetrate into the matrix. L8-2

1. Types of Absorption

a. Physical Absorption - (Dissolution) Material penetrate the matrix with no chemical reaction involved
ex. bubbling O_2 into water.
Less stable than chemical absorption, temperature dependent, high temp--lower efficiency

b. Chemical Absorption - The gas reacts with the absorbing medium to form another compound. This resulting compound is somehow retained in the absorbing medium.

$$\underset{ex.}{}\quad 2\,\underset{\text{(gas)}}{NH_3} + \underset{\text{(liquid)}}{H_2SO_4} \longrightarrow (NH_4)_2\,SO_4$$

Also temp dependent, reaction dependent

Slides L8-3a-h stress individual properties. Slide L8-3i can be used alone if individual stress is not desired

2. Absorbing Medium

a. Properties of Ideal Absorbing Medium L8-3a

(1) Relatively non-volatile L8-3b
(2) Inexpensive L8-3c
(3) Stable L8-3d
(4) Low - viscosity L8-3e
(5) Moderate foaming L8-3f
(6) Non-flammable L8-3g
(7) Non-corrosive L8-3h
(8) Non-toxic

L8-3i

Good choice which fits all of these is distilled H_2O

b. Factors Influencing Absorbing Medium Selection

(1) Solubility
(2) Reactive properties of solvent and pollutant (important in both physical and chemical absorption)
(3) Subsequent analysis

3. Absorber

L8-4a
L8-4b

Device for containing the absorbent, allowing efficient collection by the absorbent.

a. Factors Affecting Absorber Collection Efficiency

(1) Gas phase diffusion - should have some means of of diffusing the gas passing into the absorbent. This causes good mixing resulting in more efficient capture (better distribution of molecules) — L8-5

(2) Liquid phase diffusion - should have some means of allowing "fresh" absorbent to come in contact with gas. Increases efficiency

(3) Residence time - the longer the time that the gas is in the absorbent the better the collection efficiency Especially true of chemical absorption. Depends on flowrate.

(4) Bubble size - smaller the bubble the larger the surface area of gas exposed to absorbent. More surface area exposed, better the efficiency.

(5) Solubility - mentioned earlier. Refers to other factors.

(6) Reaction time - related to residence time. In chemical absorption, the reaction requires a certain amount of time. Shorter the time of reaction, better the efficiency.

(7) Flow rate - related to bubble size, residence time, reaction time.

Optimize these parameters to get high collection efficiency.

b. Types of Absorbers

(1) Fritted Glass - efficient but susceptible to clogging. Frit size (porosity) is variable. Not used much now.

L8-6

(2) Impingers - bubble is broken up by an impingement device thereby increasing surface area and increasing efficiency. Used a lot now.

L8-7

(a) Smith Greenburg - large, has a plate fitted below the bubbler opening to act as impinger.

(b) Midget - small, with bottom of the tube acting as the impinger.

4. Limitations

Having discussed the process of absorption in conjunction with bubbler sampling trains in general terms and th factors affecting collection efficienc mention some practical considerations.

a. Although an ideal absorbing medium would possess the properties mentioned previously, no absorbing solution possesses all these characteristics. For example, the Sodium Arsenite method for collecting NO_2 is ideal (1% sodium arsenite and 0.1MNaOH) in most respects. The arsenite, however, is toxic and requires a strict disposal procedure.

Discuss the limitations of the wet SO_2 method in the same fashion (i.e. toxicity of TCM which contains mercury-waste disposal problem).

Students are probab most familiar with the wet methods for the collection of NO_2 and SO_2.

b. Another limitation of collecting gaseous pollutants via absorption in a bubbler is that the collection efficiencies and interferents are sometimes unknown or poorly defined. Systematic studies (e.g. interlaboratory and intra-laboratory collaborative testing) have been carried out for the wet SO_2 and NO_2 methods establishing not only the collection efficiencies but also that these methods can be used with confidence by different groups. However, for some of the more esoteric pollutants, this is not the case.

5. Applications

Individual applications are stressed in slides L8-8a-8f. Slide L8-8f can be used as summary or in lieu of series a-e.

This technique can be used for the collection of NO_2 or SO_2 as discussed previously. Other applications can be found in the NIOSH Manual of Analytical Methods. These include:

L8-8a

(1) Collection of cyanide and total fluoride via impinger filled with 10 ml 0.1M NaOH

↓ analysis via

ion specific electrode

L8-8b

(2) Collection of Acrolein via complexation with 4-hexylresorcinol in ethyl alcohol - trichloroacetic acid in the presence of mercuric chloride

↓

forms a blue colored complex that is measured spectrophotometrically.

$$(Abs = Ebc; \quad c = \frac{Abs}{Eb})$$

L8-8c

(3) Collection of formaldehyde via reaction of formaldehyde with an acid-sulfuric

↓

acid reaction forms a purple complex that is measured spectrophotometrically.

L8-8d

These are three typical procedures for collection of gaseous pollutants by absorption.

--There are many more described in the literature and the NIOSH Manual of Analytical Methods.

L8-8e
L8-8f
(Summary)

B. Adsorption

The removal from a gas stream of a gaseous constituent by a solid matrix in which the gas molecules are deposited on the surface of the adsorbent.

L8-9

Adsorption - outside
Absorption - inside

1. Types of Adsorption — L8-10

    a. Physical Adsorption - primarily due to electrostatic forces.

    e.g.

    (1) Van der Waals Forces (define and explain)

    (2) dipole-dipole interactions, especially the strong dipole-dipole interaction of hydrogen bonding which is dominant between polar adsorbents and pollutants.

    b. Chemical Adsorption - chemical reaction takes place at the surface of the adsorbent.

2. Factors Affecting Adsorption Efficiency — L8-11

    a. Nature of the Adsorbent

    (1) Surface area - larger, better
    (2) Size and shape - rough, porous, best
    (3) Polarity
    (4) Reactivity

    b. Temperature

    c. Velocity of air stream

    d. Concentration of gases in stream

    e. Degree of adsorption

3. Ideal Adsorbent — L8-12

    Granular, size, shape
    High adsorptive capacity
    Inert
    Non-corrosive
    Readily activated
    Easy release of adsorbate

4. Typical Adsorbents — L8-13

    Carbon
    Tenax GC
    Porapack Q (and other polymeric GC solid adsorbents)
    Polyurethane foam
    Molecular sieves
    XAD series

Instructor at this point should provide some insight into the properties of at least two of these adsorbents.

Chemical structure of two typical sorbent resins
(point out the differences in chemical structures)

Gives rise to different uses - e.g. differences in polarity

L8-13a

Visuals for chemical structures of Tenax-GC and XAD are supplied.

The instructor may opt to use other typical adsorbents with which they have experience.

5. Applications and Limitations

   a. Illustrate the trade-offs involved in selecting or using a particular adsorbent.

      (1) For example, carbon is ideal in many respects:

         (a) high adsorptive capacity
         (b) granular etc.

      (2) On the other hand, carbon cartridges have the following disadvantages:

         (a) variable collection efficiency (varies with the carbon lot)

         (b) pollutant desorption efficiency varies

         (c) of all adsorbents, probably the most susceptible to artifact formation (e.g. in-situ reactions on the adsorbent surface)

   b. Adsorbent capacities are reported in the literature for different pollutants (explain what is meant by capacity - in GC this is termed breakthrough volume)

      This could be a serious sampling error if this information is not taken into account. You will saturate the adsorbent.

6. The following illustrate how some of the various adsorbents can be placed in a sampling train and the related analytical procedure.

   (a) Typical high speed organic vapor collector. L8-14

   (b) Collection of pesticides and PCBs in a polyurethane foam by placing the adsorbent (e.g. polyurethane foam) in the throat of a Hi-Vol. L8-15

   (c) The adsorption process provides pollutant concentrations that can be detected and quantified by analytical procedure.

   Once the pollutant has been collected, the analysis requires the pollutant to be removed from the adsorbent by a process such as thermal desorption. L8-16

   This thermal desorption involves heating the adsorbent until the pollutants have been desorbed. L8-17

   (d) The total sampling - collection - analysis process as a system

   Another type of enrichment technique

C. Other sampling methods

1. Freeze-out or Condensation

An excellent application of this technique is described by Fine, et al for the collection of ambient N-Nitrosodimethylamine.

a. Condensing gas constituent out of a gas stream by removing enough heat from the system so that the gas will change to a liquid when the boiling temperature is reached.

b. Freeze-out Mechanisms L8-18

(1) Ice + H_2O - 0°C

(2) Ice + Salt - -16°C

(3) Dry Ice - -79°C

(4) Liquid Oxygen* - -183°C

(5) Liquid Nitrogen - -196°C

Select the bath for the temperature required to remove the pollutant(s) of interest. Can be used for mixture separation. Used in stack sampling for moisture analysis.

*Avoid open flames when using liquid oxygen.

2. Grab Sampling

   a. Taken in short period of time and/or a limited area. Characterizes the atmosphere for that particular period of time.

   b. Types of Grab Sampling

L8-19

      (1) Evacuated Container - Flask that has been evacuated with a vacuum. As stop cock is opened, ambient air comes in to fill vacuum giving your atmospheric sample.

      (2) Purging - Air is passed (flushed) through a receptacle then sealed off to give sample.

      (3) Liquid Displacement - As liquid is drained out of bottle, air replaces it giving your sample. Caution must be taken to prevent gas of interest from reacting with or absorbing in the liquid.

      (4) Inflation - Bag is inflated with air by pumping air in. Also can be done by placing the empty bag in an evacuated leak proof rigid container. The bag will inflate to fill the evacuated space in the container.

      (5) Syringe - Air sample is drawn into a syringe. Good for GC work.

INSERT EMULSION SIDE DOWN

1/79 435 LESSON 8 12

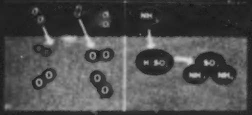
PRINCIPLE METHODS FOR GASEOUS SAMPLING

- Absorption
- Adsorption
- Condensation
- Grab sampling

1

ABSORPTION

PHYSICAL CHEMICAL


NH
H SO
SO
NH
NH

2

PROPERTIES OF AN IDEAL ABSORBING MEDIUM

- Non-volatile

3a

PROPERTIES OF AN IDEAL ABSORBING MEDIUM

- Inexpensive

3b

PROPERTIES OF AN IDEAL ABSORBING MEDIUM

- Stable

3c

PROPERTIES OF AN IDEAL ABSORBING MEDIUM

- Low-viscosity

3d

PROPERTIES OF AN IDEAL ABSORBING MEDIUM

- Moderate foaming

3e

PROPERTIES OF AN IDEAL ABSORBING MEDIUM

- Non-flammable

3f

PROPERTIES OF AN IDEAL ABSORBING MEDIUM

- Non-corrosive

3g

PROPERTIES OF AN IDEAL ABSORBING MEDIUM

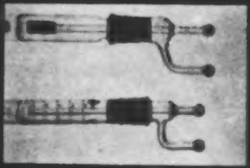
- Non-toxic

3h

PROPERTIES OF AN IDEAL ABSORBING MEDIUM

- Non-volatile
- Inexpensive
- Stable
- Low-viscosity
- Moderate foaming
- Non-flammable
- Non-corrosive
- Non-toxic

3i



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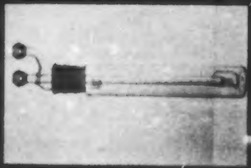


4a

FACTORS AFFECTING ABSORBER COLLECTION EFFICIENCY

- Gas phase diffusion
- Liquid phase diffusion
- Residence time
- Bubble size
- Solubility
- Reaction time
- Flow rate

5

FRITTED GLASS ABSORBER

6

IMPINGERS

Midget
Smith Greenburg
15

7

APPLICATIONS

- Collection of NO_2 or SO_2

8a

APPLICATIONS

- Collection of NO_2 or SO_2
- Collection of cyanide or total fluoride

8b

APPLICATIONS

- Collection of NO_2 or SO_2
- Collection of cyanide or total fluoride
- Collection of acrolein

8c

APPLICATIONS

- Collection of NO_2 or SO_2
- Collection of cyanide or total fluoride
- Collection of acrolein
- Collection of formaldehyde

8d

APPLICATIONS

- Collection of NO_2 or SO_2
- Collection of cyanide or total fluoride
- Collection of acrolein
- Collection of formaldehyde
- Many others as found in NIOSH Manual of Analytical Methods

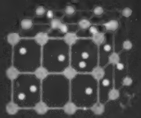
8e

APPLICATIONS

- Collection of NO_2 or SO_2
- Collection of cyanide or total fluoride
- Collection of acrolein
- Collection of formaldehyde
- Many others as found in NIOSH Manual of Analytical Methods

8f

ADSORPTION



9

TYPES OF ADSORPTION

PHYSICAL
CHEMICAL
No Reaction
React on Surface

10

NATURE OF ADSORBENT

- Surface Area
- Size and Shape
- Polarity
- Reactivity

11

IDEAL ADSORBENT

- Granular
- High capacity
- Inert
- Non-corrosive
- Readily activated
- Easy release

12

TYPICAL ADSORBENTS

- Carbon
- Tenax GC
- Porapack Q
- Polyurethane foam
- Molecular sieves
- XAD series

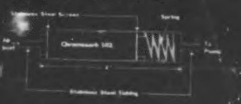
13

CHEMICAL STRUCTURES OF TYPICAL SORBENT RESINS

XAD-2
TENAX GC

13a

TYPICAL HIGH SPEED ORGANIC VAPOR COLLECTOR


Stainless Steel Screen
Spring
Chromosorb 102
Air Inlet
To Pump
Stainless Steel Tubing

14

HIGH VOLUME AIR SAMPLER FOR PCB'S

Exhaust Duct
Motor Unit
Foam Plug
Throat Extension

15

11/79 435 LESSON 8 13

Carrier Gas
Teflon Bath
Insulation
Glass Tube
Glass Wool
Injection Port Heater
Oven

ENRICHMENT
ADSORPTION COLUMN
GC Column

TYPICAL FREEZE - OUT SERIES

GRAB SAMPLING
Evacuated Container
Purging
Syringe
Bag Sampling

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: PRINCIPLES OF PARTICULATE SAMPLING

COURSE: 435 - Lesson #9
LESSON TIME: 1 hr. 15 min.
PREPARED BY: Northrop Services, Inc. **DATE:** 2/15/79

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

LESSON GOAL: To develop an understanding of the principles and instrumentation that are used in particulate sampling.

LESSON OBJECTIVES:

1. Describe three principle types of particulate collection devices: gravity, filtration, impaction and recall examples of each.
2. Identify at least two common errors in inertial collection of particulates.
3. Describe the mechanism for size fractionation by inertial sampling.
4. Define collection efficiency of an impaction device.
5. List four properties of aerosols and four properties of collecting devices which affect the collection efficiency of impactors.
6. Discuss how the following particulate samplers operate and what each is used for:
    a. Cascade Impactor
        (1) Andersen Impactor
    b. Cyclone Samplers
7. Describe the rationale for size fractionation of ambient particulate matter.
8. Define the differences between respirable and non-respirable particulate matter.

9. Describe how the dichotomous sampler fractionates respirable and non-respirable particulate matter.

10. Discuss some of the advantages and disadvantages of the three types of filter materials.

SUPPORT MATERIAL AND EQUIPMENT:

Objective Handout

Carousel Projector with slide tray

SPECIAL INSTRUCTION: None

SELECTED REFERENCES:

Corn, M., Esmen, N. A., "Field Sampling of Airborne Particulates", American Laboratory, July, 1978, p.13.

Dzubay, T. G., Hines, L. E., and Stevens, R. K., "Particle Bounce Errors in Cascade Impactors", Atmospheric Environment, 10:229 (1976)

Stevens, R. K. and Dzubay, T. G., Dichotomous Sampler - A Practical Approach to Aerosol Fractionation and Collection" US Environmental Protection Agency, EPA-600/2-78-112, 1978.

Wedding, T. E., McFarland, A. R., and Cermak, T. E., "Large Particle Collection Characteristics of Ambient Aerosol Samplers", Environ. Sci. and Tech., 11, No. 4:387 (1977).

Gelman, C., and Meltzer, T.H., "Membrane Filters" Anal. Chem., 51 (6) 22A-31A (1979).

Smith, W. B., Cushing, K. M., and Lacey, G. E., "Andersen Filter Substrate Weight Loss" US Environmental Protection Agency, EPA-650/2-75-022, 1975.

Stevens, R. K., and Dzubay, T. G., "Recent Developments in Air Particulate Monitoring" IEEE Transactions on Nuclear Science, Vol. NS-22, No. 2, p. 849-855 (1975).

CONTENT OUTLINE

Course: 435 - Lesson #9
Lecture Title: PRINCIPLES OF PARTICULATE SAMPLING

NOTES

Review lesson objectives with the students

I. INTRODUCTION

In particulate sampling, as in gaseous sampling, there are many methods and combination of methods for sampling. L9-1

The methods to be discussed in this lecture are:

1. Gravity L9-2
2. Filtration L9-3
3. Impaction L9-4

The general requirements of any particulate collection device are: L9-5a

1. Low pressure drop L9-5b
2. High and known collection efficiency L9-5c
3. Resistant to chemical and physical attack L9-5d
4. Resistant to moisture L9-5e
5. Withstand high temperature and/or extreme low temperatures L9-5f
6. Collected material easily removed L9-5g
7. Low noise, low cost and maintenance requirements.

II. GRAVITY L9-6

Dustfall jar best example, usually made of resistant material. Discusss only brief

L9-7

Jar is often contained in stand which serves to protect the jar from spilling. Wire rim to protect it from collecting bird droppings. Sampling period is usually 30 days, but can be variable. Results are calculated by filtering liquid, then weighing solids.

III. FILTRATION L9-8

Hi-Vol and tape samplers are examples.

High Volume sampling was discussed in detail in a previous lecture

The tape sampler was also used for episode monitoring at one time and also used for fluoride sampling to some extent. Modified Hi-Vol reference method now used in episode monitoring.

Properties of Filter Media in Common Use L9-9

1. Cellulose Filters - originally designed for liquid solid separation L9-10

L9-11

Advantages:

Low ash content	Good collection efficiencies
Generally inexpensive	Low metals background

Use in a variety of applications

Disadvantages:

Pressure drop is often high

Non-uniform flow and variable collection efficiencies

Hygroscopic

Artifact formation ($SO_4^{=}$ and NO_3^{-})

Note: Filtration samplers do not operate solely as a "strainer"but also uses diffusion, inertia, and electrical forces. See Course Manual for a more detailed explanation.

2. Glass Fiber Filters

L9-12

Finely spun glass fibers pressed with an organic binder; binder is usually flashfired off for air sampling.

Advantages

L9-13

High collection efficiency

Non-Hygroscopic

Moderate Pressure drop

Used routinely in high volume sampling

Refer to table in Course Manual for specific filter names and specifications.

Disadvantages

Fragile - breaks apart easily

Not especially suited for microscopy.

Difficult to remove particulate matter

Variable composition

Contamination, commonly Fe, Al, Mg, Na, and K.

Difficult to ash - high silica content

Filters are not neutral pH - aids in artifact formation, especially for sulfates and nitrates.

3. Membrane Filters

L9-14

Generally dry gels of cellulose esters.

They are commonly cellulose acetate or cellulose nitrate.

Manufacturing process can control both pore size and internal membrane structure.

These filters can be made of Teflon.

Advantages L9-15

Selective pore size

Adaptability--for example can be manufactured for a variety of applications, e.g. low ash easily dissolved, etc.

Relatively inexpensive

Moderately non-corrosive

Suited for microscopic studies

Disadvantages

High pressure drop

Tend to be brittle and need a backing

Short sampling times -- tend to plug quickly in areas of high particulate concentration

Static charge build-up

Variations in pore diameter.

See course manual for more details on this

IV. IMPACTION L9-16

Inertia: A particle with a constant velocity is resistant to changes in speed and direction

L9-17

This property of particles moving in an air stream is used in air sampling to collect particles in groups of varying size. Larger particles which do not have the momentum to remain in the air stream when the air makes a quick change in direction and then collide with and remain on the impaction or collection surface.

L9-18

The momentum and inertia of particles are properties of aerosols that are utilized to give size fractionation in impaction devices. These properties also affect the collection efficiency of a particular impaction device. The efficiency is that fraction of particles in an incident aerosol stream that are retained on the collection surface of the sampling device. The properties of collection devices that affect collection efficiency are:

1. Jet size - affects velocity of the air stream and thus aerosol velocity. L9-19
   For multistage impaction, typical velocities:
   1st stage ~ several m/s
   last stage > 50 m/s

2. Jet shape - though not that significant. L9-20

3. Distance between the jet and collection surface. Usually decreases with each successive stage... controls degree of deflection of particle stream... large deflection angle required for small particles. L9-21

4. Collection Surface - Shape, texture, degree of attraction (e.g. sticky or hard) L9-22

*Factors affecting the inertia of particles and the collection efficiency of an impactor. L9-23a L9-23b

. Velocity of the air stream (the velocity of the air stream imparts a certain velocity to the particle) L9-23c

. Particle mass and density L9-23d

. Electrical forces: attractions or repulsions that build up on the collection surface L9-23e

. Mobility - a function of particle size, mass and density.

Several of these properties combined are referred to as stickiness of particles.

Examples of Impaction Devices

Impaction collection devices are used to separate particulate matter into size fractions. One type is generally referred to as a "Cascade Impactor". The cone shape of the entrance nozzle increases the air velocity and particles are separated according to mass because particles with the higher mass fall out first... intermediate particles fall out in later stages. L9-24

1. A type of Cascade Impactor is the Andersen Sampler. This sampler uses various numbered and sized holes to produce different jet velocities which gives rise to a size fractionation among the various stages. There are two types: viable (for biological sampling) which uses petri plates with selective media and non-viable which uses sticky plates or filter paper for collection. L9-25 L9-26 L9-27 L9-28

2. A modification of the High Volume Sampler is the High Volume Andersen Sampler. With slight variations, it operates similar to the Cascade impactor. It is adapted to fit on standard High Volume Samplers. It has a higher (20 cfm) sampling rate and better collection efficiency. The impaction occurs as the stream turns from one hole to the next. Sierra cascade impactor operates with slits instead of holes and can operate at a flowrate of 40 cfm or greater.

L9-29
L9-30

Another type of impaction device is the Cyclone Sampler. This is an inertial separator without moving parts. It separates particulate matter from a carrier gas by transforming the velocity of an inlet stream into a double vortex confined within the cyclone. The entering gas spirals downward at the outside and spirals upward at the inside of the cyclone outlet. The particulates, because of their inertia, tend to move toward the outside wall, from which they are led to a receiver.

L9-31
L9-32

- Not efficient collectors of particles with a diameter <5μm.
- Often used as a preseparator with filters.
- Disadvantage of collecting large particle fraction on their inner walls which must be cleaned off.

L9-33

3. Another type of impaction device is the Rotorod Sampler. This is really impaction in reverse; instead of particles being moved onto the collection surface, the collection surface is moved into the particles. Rotating arms contain removable bars which are coated with a sticky substance. The bars are removed after sampling and analyzed microscopically. This sampler has been used mainly in pollen sampling.

L9-34
Mention only briefly

Limitations and Sources of Error for Cascade Samplers L9- 35 a

1. Particle shattering; this gives rise to inaccurate size fractionation. This is especially important in particle size determinations and respirable dust studies. Specifically, particles > 200 μm are often shattered; > 50 μm , some particles are lost by impaction on walls; <5 μm, difficult to collect because momentum of particulates is not appreciably different from air stream momentum.

L9-35b

2. Re-entrainment of particles and wall losses - again causes inaccurate sizing results.

3. Limited sample quantity - true for many of the low flow rate, high pressure drop samplers, that use membrane filters. L9-35c

V. Rationale for size fractionation and the potential new particulate standard.

The 1977 Clean Air Act Admendments required that existing ambient pollutant standards be reviewed by 1980. One that they will consider changing is TSP. Since the total suspended particulates measurement includes particles which are both inhalable (less than 15 μm) and not inhalable (greater than 15 μm), non-attainment of the TSP standard at present may be the result of particulate which does not constitute a health hazard, even though they do cause adverse public welfare effects.

Present (TSP) Standard has problems.

- Larger particles > 15 μm are not very harmful
- Hi-vol inaccuracies (see Lesson 4) L9-36
- Wind blown dust and sand causes high levels of TSP in Western states.

Particles smaller than 15* μm are inhaled to at least the upper respiratory tract.

Secondary data may be required on "fine" size fraction (smaller than 2.5 μm) in order to develop control strategies but will not be part of the standard. At one time it was thought that the "fine" fraction <2.5 μm vs. the course fraction > 2.5 < 15 μm was the more important health hazard, but since then it was found that inhalables posed an equal threat. - (One reason for the design of the Dichotomous Sampler - evaluate the need for a "respirable" "fine" standard).

If an additional or revised standard is found necessary it would likely be proposed in the 1980's. Of the several approaches for a standard Reference Method for collecting Inhalable Particulates the Dichotomous Sampler has been given much attention in EPA evaluation and testing. L9-37

Dichotomous Sampler

Originally designed to meet the need of separating "respirables" from "non-respirable" the dichotomous sampler has the added advantage of collecting both the fine and course modes to give the total < 15 μm particles or Inhalables.

*It is also believed that large particles can enter into the digestive system where they too may pose a threat to human health, e.g., cancer of the stomach.

L9-38

Consists of two modules, the sampling module and the control module. The two separate modules allow locating the sampling module on the roof of an air-quality monitoring station with the control module inside. The inlet is designed to have an upper particle size cut-off to prevent entry of very large particles. (greater than 15 μm). The sampled particles smaller than 15 μm pass through the flow-straightening inlet tube and enter the virtual impactor head. The particles are then accelerated through the impactor nozzle. By virtue of their greater inertia, particles $>$ 3.5 μm impact into the "void" of the receiver tube. To prevent back flow, the receiver tube has a flow rate of 0.1 m^3/hr. The coarse particles greater than 3.5 μm, and 1/10 of the fine particles are collected on a 37mm Teflon filter. The fine-particles flow at a flowrate of 0.9 m^3/hr. (15.0 ℓpm) around the receiver tube and are collected on a second 37 mm filter. L9-39

Advantages of the Dichotomous Sampler L9-40

1. Separates particles into respirable and non-respirable fractions.

2. "Bounce" and particle shattering found in Cascade impactors is eliminated

3. The sampler is omnidirectional (e.e., does not suffer from the wind directional sensitivity like that of the Hi-Vol sampler)

4. Particulate is collected on membrane filters which facilitates chemical analysis by x-ray fluorescence - (gives elemental composition). (Teflon filters may be used).

Other more cost effective approaches to collecting the Inhalable fraction have been suggested: (1) Tape Samplers (2) Size select inlet - Adapts to a standard Hi-Volume Sampler (SSI). L9-41

Omni-directional inlet. Uses inertial impaction to procure a clear particle size cut-point of 15 μm. Flow must be held constant (e.g. 40 cfm) to achieve this distinct cut-point. (See lesson on Inertial Samplers). Collects particles on a standard 8 x 10 glass fiber filter. L9-42

Review with class questions (see objectives)

1. What are three common filter materials used in atmospheric sampling?
2. What are two sources of error in inertial or impaction collectors?
3. Explain the rationale for size fractionation of particulate matter?
4. What are the properties of impaction collectors that affect collection efficiency?

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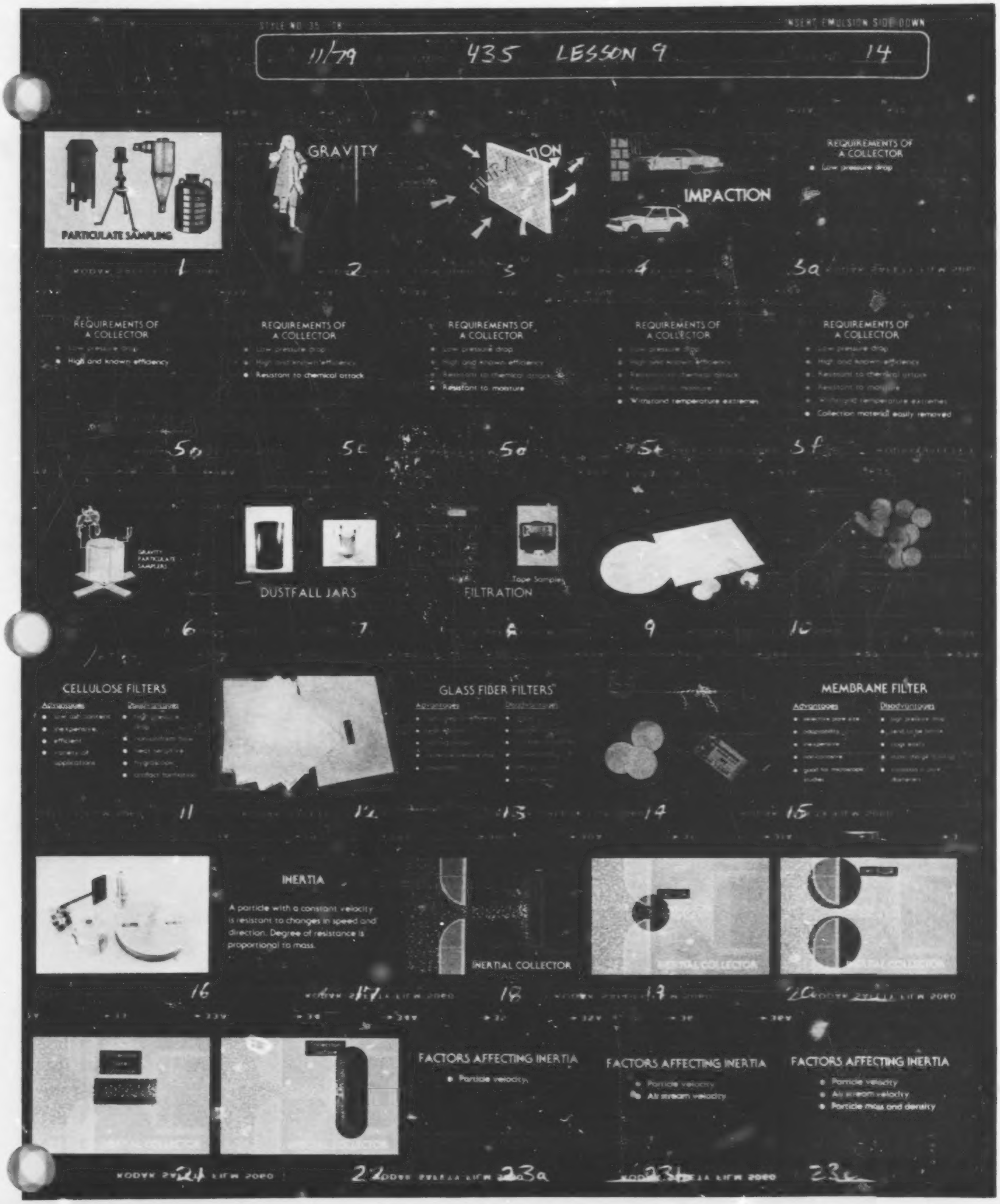
INSERT EMULSION SIDE DOWN

11/79 435 LESSON 9 14



PARTICULATE SAMPLING

1

GRAVITY

2

FILTRATION

3

IMPACTION

4

REQUIREMENTS OF A COLLECTOR
- Low pressure drop

5a

REQUIREMENTS OF A COLLECTOR
- Low pressure drop
- High and known efficiency

5b

REQUIREMENTS OF A COLLECTOR
- Low pressure drop
- High and known efficiency
- Resistant to chemical attack

5c

REQUIREMENTS OF A COLLECTOR
- Low pressure drop
- High and known efficiency
- Resistant to chemical attack
- Resistant to moisture

5d

REQUIREMENTS OF A COLLECTOR
- Low pressure drop
- High and known efficiency
- Resistant to chemical attack
- Resistant to moisture
- Withstand temperature extremes

5e

REQUIREMENTS OF A COLLECTOR
- Low pressure drop
- High and known efficiency
- Resistant to chemical attack
- Resistant to moisture
- Withstand temperature extremes
- Collection material easily removed

5f

6

DUSTFALL JARS

7

FILTRATION

8

9

10

CELLULOSE FILTERS

Advantages
- low ash content
- inexpensive
- efficient
- variety of applications

Disadvantages
- high pressure drop
- nonuniform flow
- heat sensitive
- hygroscopic
- artifact formation

11

12

GLASS FIBER FILTERS

Advantages
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

Disadvantages
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

13

14

MEMBRANE FILTER

Advantages
- selective pore size
- adaptability
- inexpensive
- non-corrosive
- good for microscopic studies

Disadvantages
- high pressure drop
- tend to be brittle
- clogs easily
- static charge buildup
- [illegible]

15

16

INERTIA

A particle with a constant velocity is resistant to changes in speed and direction. Degree of resistance is proportional to mass.

17

INERTIAL COLLECTOR

18

INERTIAL COLLECTOR

19

INERTIAL COLLECTOR

20

INERTIAL COLLECTOR

21

INERTIAL COLLECTOR

22

FACTORS AFFECTING INERTIA
- Particle velocity

23a

FACTORS AFFECTING INERTIA
- Particle velocity
- Air stream velocity

23b

FACTORS AFFECTING INERTIA
- Particle velocity
- Air stream velocity
- Particle mass and density

23c

4/79 435 LESSON 9 15

FACTORS AFFECTING INERTIA

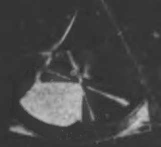
- [illegible]

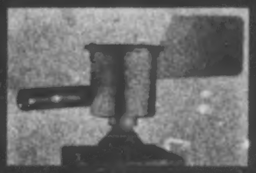
FACTORS AFFECTING INERTIA

- Particle mobility

CASCADE IMPACTOR

ANDERSON SAMPLER





CASCADE SAMPLER

- Particle shattering

CASCADE SAMPLER

- Re-entrainment and wall losses

CASCADE SAMPLER

- Limited sample quantity

ADVANTAGES OF DICHOTOMOUS SAMPLERS

41

42

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: LABORATORY SAFETY BRIEFING

COURSE: 435 - Lesson #10
LESSON TIME: 30 Minutes
PREPARED BY: Northrop Services, Inc. **DATE:** 2/21/79

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

LESSON GOAL: Familiarize students with general safety considerations.

Each lab instructor will review safety in his or her laboratory.

Generally,

1. Safety glasses will be worn at all times while in the laboratory.
2. Lab coats should also be worn. -- Never worn to cafeteria, etc.
3. No canvas, sandals, or open-toe-shoes.
4. Point out fire extinguishers in each lab.
5. Clearly show emergency exits.
6. Absolutely no smoking, eating, or drinking in the lab.
7. No horseplay.
8. Fire safety equipment, what and how is alarm sounded, exit routes, etc.
9. Safety facilities, (e.g. eye flush, showers, hoods)
   - A. location
   - B. operation

In addition to the above general safety precautions, specific safety considerations for the High Volume Sampler and Standard Test Atmospheres labs follow:

1. High Volume Sampler Lab
   - A. Check all electrical cords for cracked insulation and loose plugs.
   - B. If it is necessary to run extension cords on floor, the cords must be securely taped to floor.

C. Rootsmeter stands must be sturdy and stable.

2. Test Atmospheres Lab

A. Compressed gas cylinder safety.

1. All cylinders must be clamped to lab benches or placed in cylinder stands.

2. Cylinder valve protection caps must be left on cylinders until the cylinders have been properly secured and are ready for use.

3. Cylinders should be moved by using a suitable hand truck (one that has a retaining chain or belt).

4. No part of a cylinder should be subjected to a temperature above 125°F.

5. Eye washes and safety showers should be located near cylinder use areas, but out of the immediate area which is likely to become contaminated in the event of a large gas release.

6. When cylinders are considered empty, the following procedure should be followed:

a. cylinder valves should be closed
b. valve protection caps should be attached to the cylinders
c. cylinders should be labeled "Empty"
d. cylinders should be placed in a proper storage area (segregated from full cylinders)

B. Compressed gas cylinder regulator operation

1. Attach the regulator to the cylinder without forcing threads.

2. Check for leaks using a soap solution.

3. Turn the delivery pressure adjusting screw until it turns freely.

4. Open the cylinder valve slowly until the cylinder pressure gage on the regulator registers the cylinder pressure.

5. With the flow control valve at the regulator outlet closed, turn the delivery pressure adjusting screw clockwise until the required delivery pressure is reached.

6. Open the flow control valve until the required flow rate is obtained.

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: PROBLEM SESSION II

COURSE: 435 Lesson #11
LESSON TIME: 45 Min.
PREPARED BY: Northrop Services, Inc. **DATE:** 2/1/79

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

LESSON GOAL:

To review Problem Set II with the students

LESSON OBJECTIVES:

At the conclusion of this session, the student should be able to:

-- Understand and work the exercises in Problem Set II

SUPPORT MATERIALS:

Overhead Projector or Blackboard

Laboratory and Exercise Manual

SPECIAL INSTRUCTIONS:

Review as completely as possible

Answer all student questions.

435 - ATMOSPHERIC SAMPLING

PROBLEM SET II

EXAMPLE PROBLEM

2. A High-volume sampler at site #37 ran for 24:00 hours with an initial visifloat reading of 55 and a final visifloat reading of 53. The initial (tare) weight of the filter was 4.5288 grams, under equilibrium conditions. After sampling and re-equilibration the filter and sample weighed 4.6437 grams.

   Determine the concentration in $\mu g/m^3$ using the following information:

   (a) An orifice device numbered #73457 was calibrated in the lab with the following results. The temperature and pressure in the lab was 24°C and 762 mm Hg respectively.

Resistance Plate No.	Volume Passed ft^3	Time (min)	ΔP_m mm Hg	ΔP_1 in. of H_2O
5	200	5.553	93	2.95
7	200	4.463	80	4.7
10	300	5.515	66	7.2
13	300	4.925	55	9.5
18	300	4.488	46	11.7

   (b) The high volume sampler at site #37 was calibrated using device numbered #73457 in the field with the following results. NOTE: The temperature was 10°C and pressure 770 mm Hg at the time of calibration.

Plate No.	ΔP_2 in. of water	Visifloat Reading
5	2.85	34
7	4.40	42
10	6.25	51
13	7.70	57
18	9.40	62

SOLUTION:

1. Appropriate calibration curves for orifice unit should be drawn up as follows:

(a) Volumes must first be converted from ft^3 (as read off rootsmeter) to m^3 using a conversion factor of .02832 m^3/ft^3. This yields (V_m) 5.6m^3 for 200 ft^3 and 8.4m^3 for 300 ft^3.

(b) Since the orifice device lowers the pressure within the rootsmeter below atmospheric by ΔP_m we must correct each volume by that amount using:

$$V_{actual} = V_m \text{ (measured) } \left(\frac{P_{atm} - \Delta P_m}{P_{atm}}\right)$$

$$\text{Plate no. 5 - } V_{actual} = 5.6m^3 \left(\frac{762 \text{ mmHg} - 93 \text{ mmHg}}{762 \text{ mmHg}}\right)$$

$$V_{actual} = 4.92m^3 \qquad V_a = \text{Actual Volume}$$

Do this for plates nos. 7-18 with the following results: True air Volume: ($V_a m^3$) = 5.01, 7.67, 7.79, 7.89m^3.

(c) Using these true air volumes you can now divide by the appropriate times it took these volumes to pass through the rootsmeter to give you true flowrate Q_a m^3/min.

$$\frac{\text{Volume}}{\text{Time}} = \text{flowrate } (Q_a) \text{ plate no. 5} \quad \frac{4.92m^3}{5.553 \text{ min}} = \underline{.886}m^3/\text{min}$$

Do this for plate nos. 7-18 with the following results: 1.123, 1.39, 1.76m^3/min. (Q_a)

(d) Plot Q_a m^3/min vs. ΔP_1 in inches of H_2O (pressure drop from orifice device) on log-log paper. This curve is for lab conditions of 24°C and 762 mm Hg. (See Fig. I)

(e) In this case, field conditions were different from lab conditions (temp and press.), therefore a new calibration curve should be drawn up. (In Fig. I this is plotted alongside of the lab orifice curve)

The Equation for temperature and pressure corrections for flows is as follows:

$$Q_a \text{ (corrected) to field condition} = Q_a(\text{lab}) \sqrt{\frac{T_2}{T_1} \cdot \frac{P_1}{P_2}} \qquad \text{(Note square root sign)}$$

$$\boxed{T^\circ K = 273 + T^\circ C} \quad \text{plate no. 5: } Q_a \text{ corrected to field condition} = .866 \sqrt{\frac{283}{297} \cdot \frac{762}{770}}$$

$$Q_a \text{ corrected to field condition} = \underline{.860} \; m^3/\text{min}$$

Do this for plates nos. 7-18 with the following results: 1.09, 1.34, 1.53, 1.70 m^3/min. Plot new Q_a's against ΔP_1 for curve reflecting field conditions. (See Fig. I)

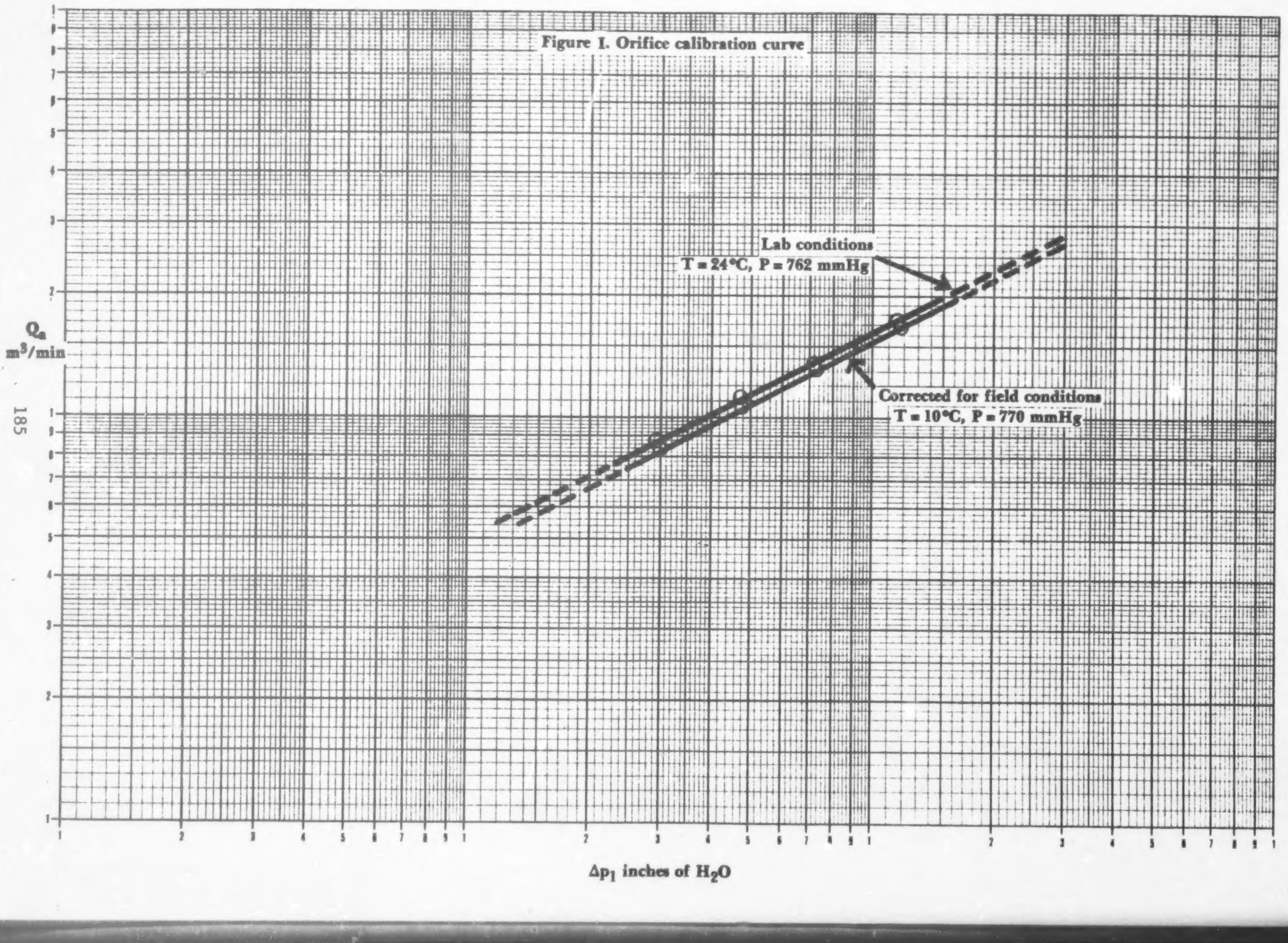


Figure I. Orifice calibration curve

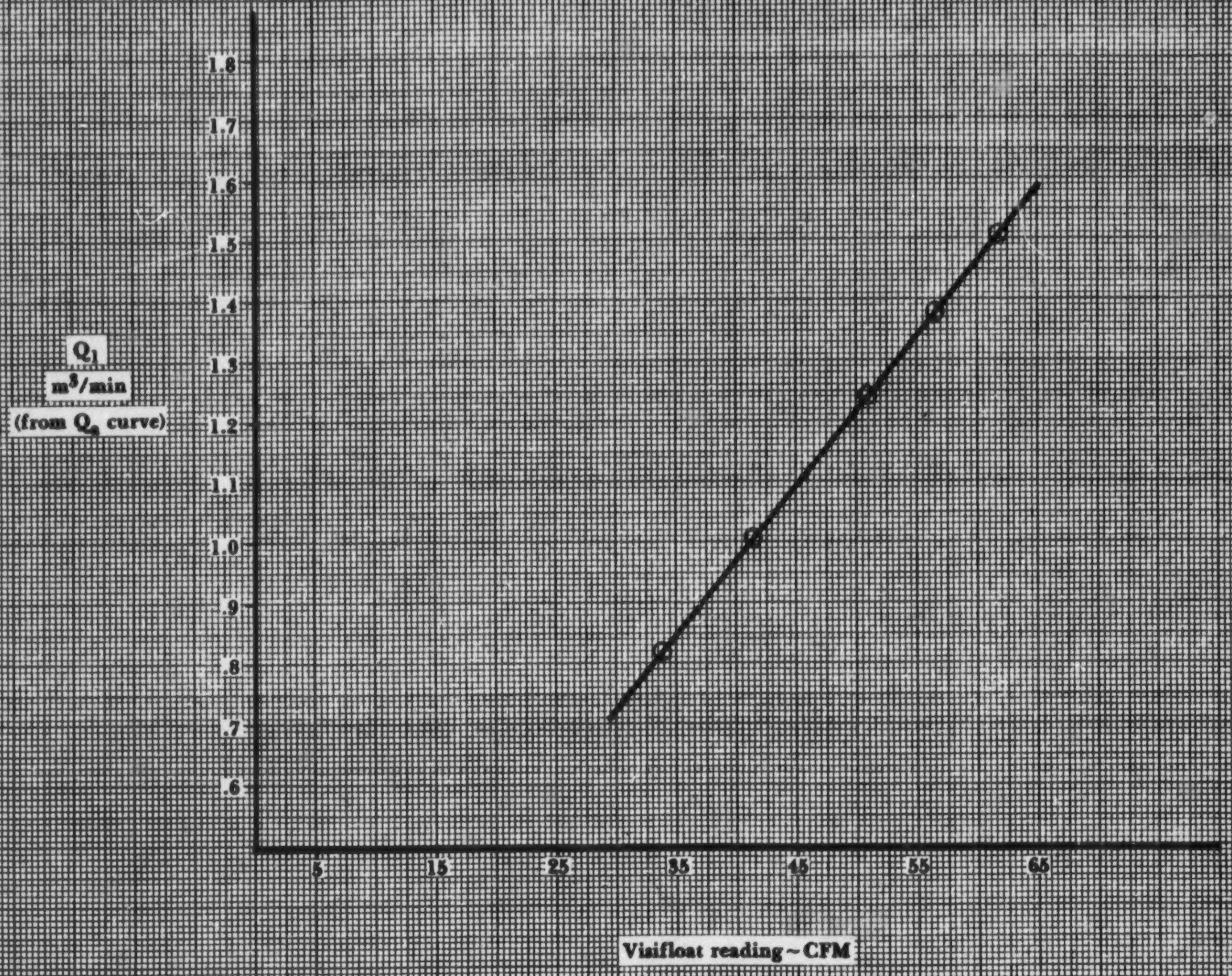


Figure II. Visifloat calibration curve

2. Using field condition curve just plotted find a Q_a (true flowrate) that corresponds to the ΔP_2 as read in the field (use ΔP_1 axis on curve). Plot these Q_a (now designated Q_1) against your visifloat reading on linear paper. These extrapolated Q_1's for plates 5-18 are as follows: .82, 1.03, 1.24, 1.37 and 1.5 m^3/min (check these yourself). (See Fig. II)

3. To determine concentration of particulates in $\mu g/m^3$ use the formula.

$$\text{TSP } \mu g/m^3 = \frac{(W_f g - W_i g) \times 10^6 \text{ (conversion of g to } \mu g)}{\underset{(m^3/min)}{\left(\frac{F_f + F_i}{2}\right)} \times t(min)}$$

---

t = our sample ran for 24 hours x $\frac{60 \text{ min}}{\text{hr}}$ = 1440 min

convert flow indication readings to Q_1 readings from curve II

F_f 55 = 1.33 m^3/min

F_i 53 = 1.28 m^3/min

$$\left(\frac{Q_F + Q_I}{2}\right) = \left(\frac{1.33 + 1.28}{2}\right) = 1.3 \text{ m}^3/\text{min}$$

$$W_f g - W_i g = 4.5288g - 4.6437g = .1149 \text{ grams} \times 10^6 \frac{\mu g}{g} = 1.149 \times 10^5 \ \mu g$$

$$\text{TSP} = \frac{1.149 \times 10^5 \ \mu g}{1.3 \text{ m}^3/\text{min} \times 1440 \text{ min}} = \boxed{6.13 \times 10^1 \ \mu g/m^3}$$

PROBLEM SET 2

(1) An orifice calibration unit was calibrated in the laboratory with the following results (24°C, 762 mm Hg)

Vm cubic feet	T minutes	ΔPm mm Hg	ΔP_1 inches of water
200	5.7	95	3.0
200	4.49	82	5.0
300	5.53	60	7.9
300	4.86	56	10.2
300	4.45	48	12.7

A high-volume sampler and visifloat were calibrated in the field at 24°C and 762 mm Hg with the above orifice calibration unit with the following results:

ΔP_2 inches of water	Visifloat reading
3.1	31
4.9	38
7.4	47
9.2	52
10.9	57

Plot the appropriate curves and use these to solve the following problem:

> A high-volume sampler was run for 24:00 hours with an initial visifloat reading of 57 and a final visifloat reading of 55. The initial (tare) weight of the filter paper was 4.5314 g., after sampling and re-equiibration to less than 50% relative humidity, the filter paper and sample weighed 4.6524 g. Determine the concentration of particulate expressed in micrograms per cubic meter, under the following conditions.

	Temp	Barometric Pressure
Lab conditions	24°C	762 mm Hg
Field conditions	24°C	762 mm Hg

(2) Determine the concentration of particulates if the above experiment was run under the following conditions.

	Temp	Barometric Pressure
Lab conditions	24°C	762 mm Hg
Field conditions	36°C	711 mm Hg

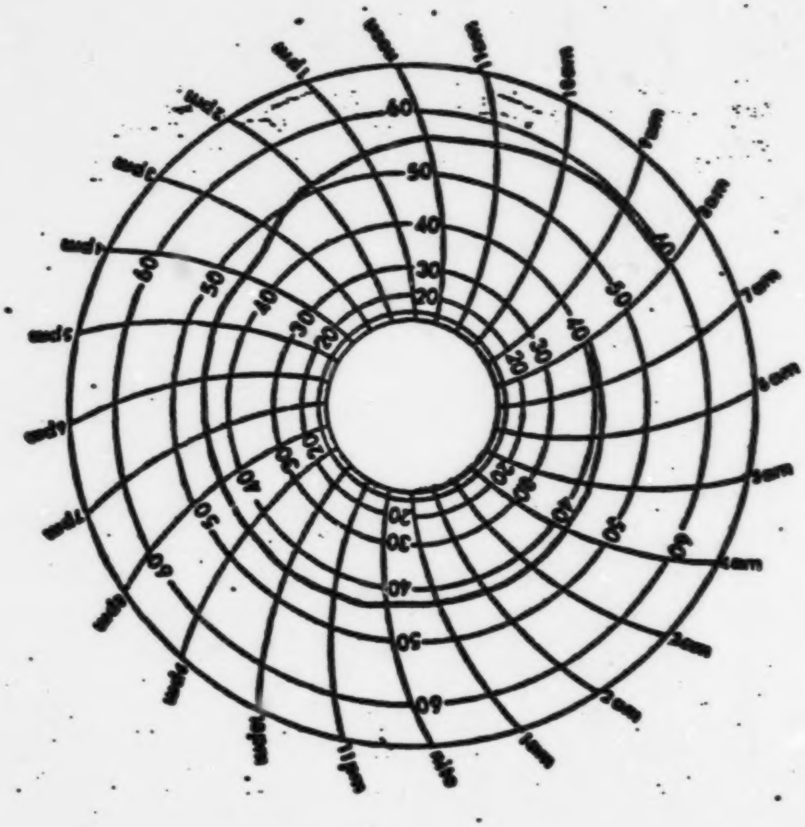
(3) A high-volume sampler was run for 24:00 hours. The weight gain on the filter was 0.2550 grams. The sampler has a recorder for recording the actual air flow over the entire sampling period and the attached chart was obtained during this sampling run.

Using the calibration curves from problem #1, calculate the micrograms per cubic meter using the following methods:
(assume Transducer curve is identical to visifloat curve)

A. Use recorded air flows at start and end of sampling period.

B. Use recorded air flow for every two (2) hours.

C. Assume that the result in B is correct and calculate the % error in A.



Problem 2, Figure 2-1 Pressure transducer recording for Problem 2.3

1. V_m = Volume measured by rootsmeter at reduced pressure

P_a = Barometric pressure

Δp_m = Read off mercury manometer

V_m in ft^3 can be converted to m^3 at this step. However, flows can be calculated in ft^3/min and placed on graphs. We are converting at this step, and graphs reflect this.

$200\ ft^3 = 5.66\ m^3$, $300\ ft^3 = 8.49\ m^3$ from $\left(.02832\ \frac{m^3}{ft^3}\right)$

correct each volume (V_m) by this formula:

$$V_a = (Vm)\left(\frac{Pa - \Delta pm}{Pa}\right)$$

V_a = actual volume corrected for pressure drop caused by orifice

(1) $V_a = 5.66\ m^3$ (formerly 200 ft^3) $\bullet \left(\frac{762mmHg - 95\ mmHg}{762\ mmHg}\right) = \underline{4.954m^3}$

(2) $V_a = 5.66\ m^3 \bullet \left(\frac{762mmHg - 82\ mmHg}{762\ mmHg}\right) = 5.05m^3$

(3) $V_a = 8.49m^3 \bullet \left(\frac{762 - 60}{762}\right) = 7.821m^3$

(4) $V_a = 7.865m^3$

(5) $V_a = 7.955m^3$

$V_a(m^3)$	Time (min)
4.954	5.70
5.050	4.49
7.821	5.53
7.865	4.86
7.955	4.45

$$Q_a\left(\frac{m^3}{min}\right) = \frac{V_a}{Time}$$

Q_a (m^3/min)	Δp_1 (inches of water)
0.869	3.0
1.125	5.0
1.414	7.9
1.618	10.2
1.787	12.7

A curve for your calibrated orifice consists of plotting Qa vs. Δp_1 (Fig I) (on Log-Log paper)

K+E LOGARITHMIC 2 X 3 CYCLES
KEUFFEL & ESSER CO.
46 7320
MADE IN U.S.A.

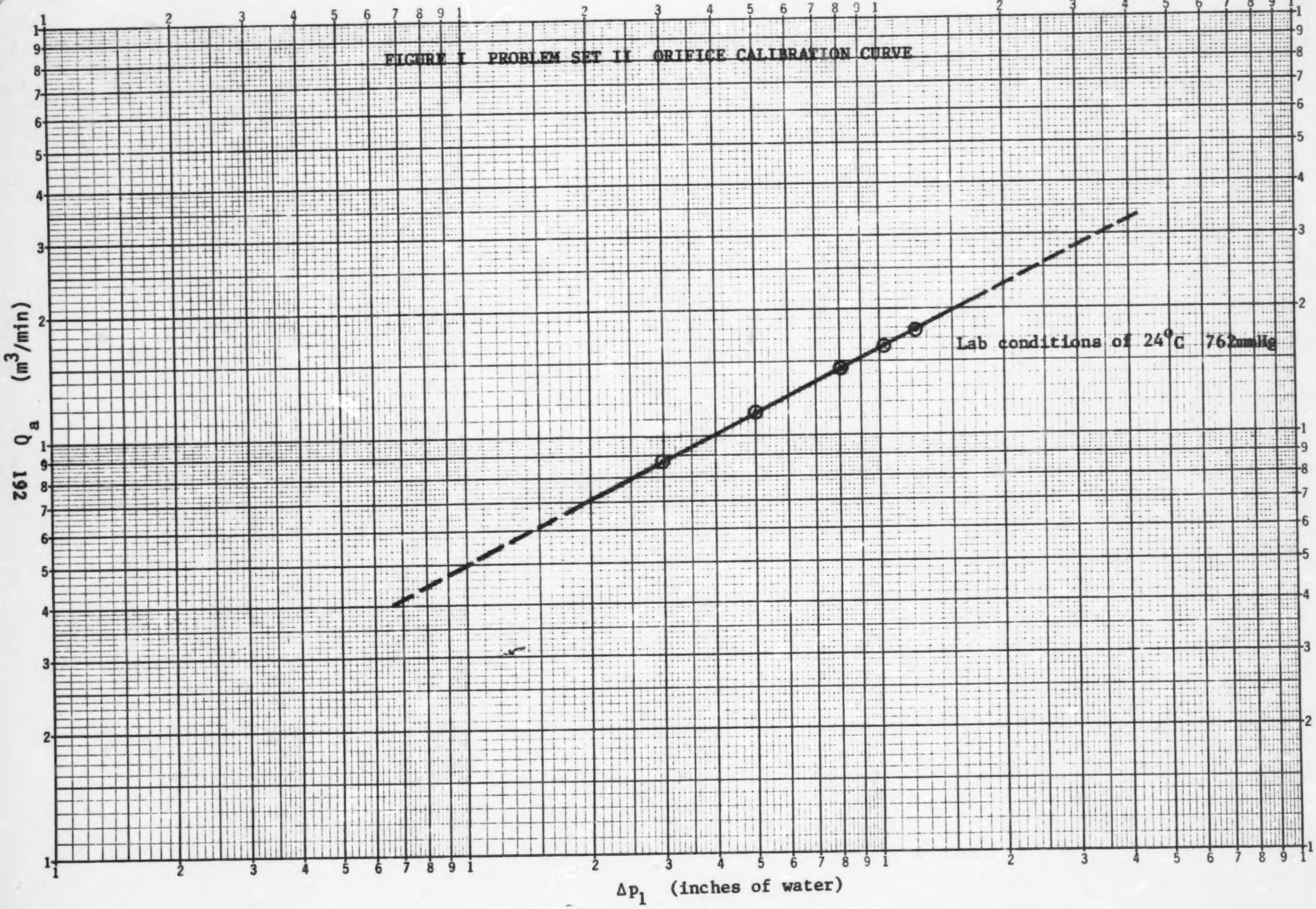


FIGURE I PROBLEM SET II ORIFICE CALIBRATION CURVE

The next step consists of calibrating a visifloat against the calibrated orifice. Because you are at the same conditions in the field as you were in the lab... No corrections are needed.

The Δp_2 (inches of water) can be related to a volume flow by using the log-log plot from your calibrated orifice.

Δp_2 (inches of water) (ΔP_1 on plot)	Q_1 m^3/min from log-log Plot (Q_a on plot)	Visifloat Reading
3.1	.88	31
4.9	1.12	38
7.4	1.38	47
9.2	1.52	52
10.9	1.68	57

Plot visifloat reading vs. flow (Q_1) (Fig. II) on linear paper.

This is a curve for the calibrated visifloat.

Use this curve to convert flow indication readings (visifloat) to actual flow readings Q_1 m^3/min.

$F_i 57 = 1.68\ m^3/min$

$F_F 55 = 1.62\ m^3/min$

$$\text{Average Flow} = \left(\frac{1.68 + 1.62}{2}\right) = 1.65\ m^3/min$$

$mass_f - mass_i = .1210g$

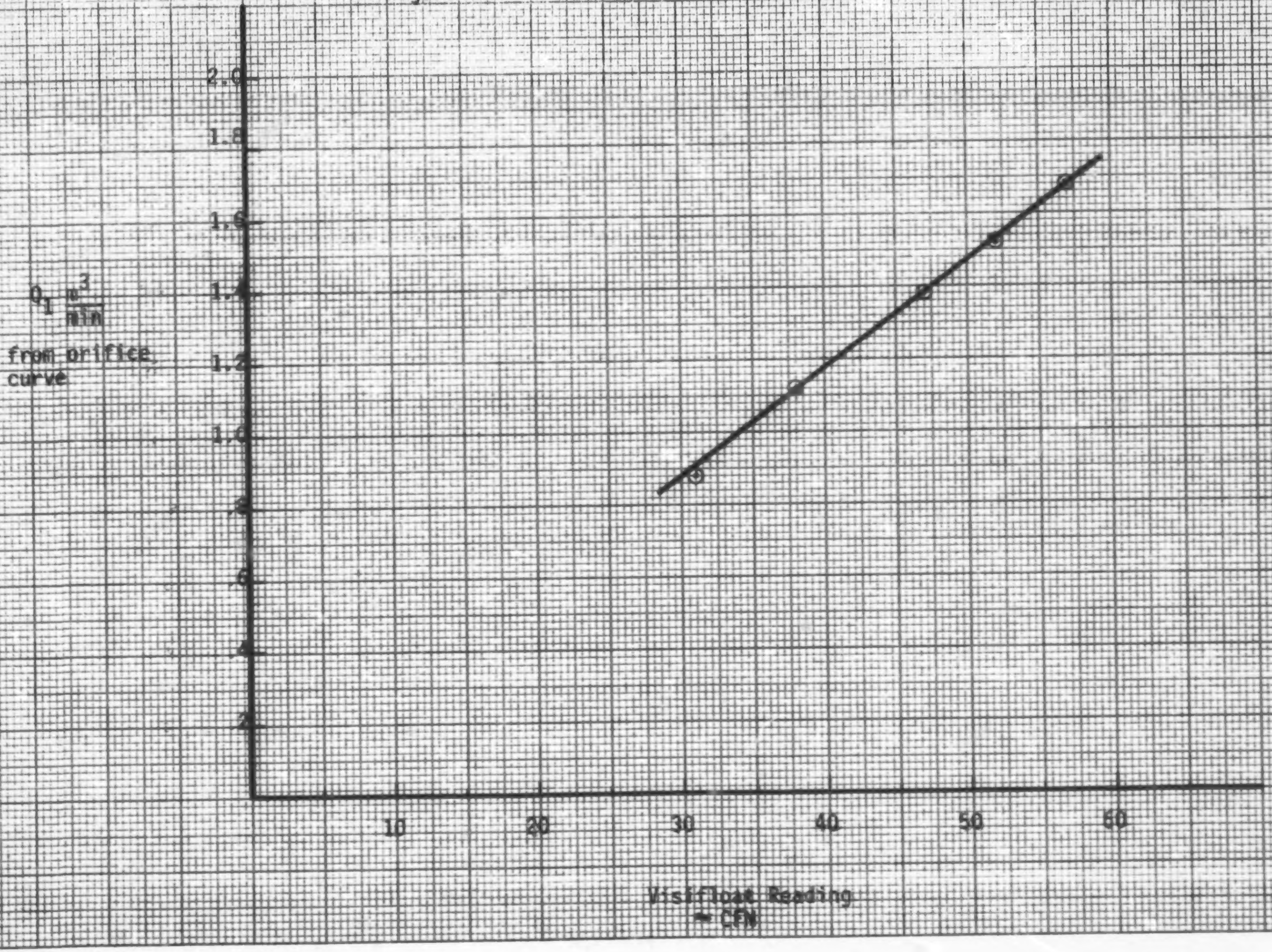
$$\text{TSP in } \frac{\mu g}{m^3} = \frac{\left(Mass_f(g) - Mass_i(g)\right)\left(10^6\ \frac{\mu g}{g}\right)}{\left(\text{AVE flow rate } \bar{Q}_1\ (m^3/min)\right)\left(t(min)\right)}$$

$$\text{TSP in } \frac{\mu g}{m^3} = \frac{\left(.1210g\right)\left(10^6\ \frac{\mu g}{g}\right)}{\left(1.65\frac{m^3}{min}\right)\left[\left(24\text{ hrs.}\right)\left(\frac{60\text{ min}}{hr}\right)\right]}$$

$$= \frac{50.9\ \mu g}{m^3}$$

K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1323

Figure II Visifloat Calibration Curve



2. Now, field conditions have changed and are different from the conditions at which the orifice was calibrated. Therefore, the flow must be corrected to the new temperature and pressure.

Average flow reading = 1.65 m^3/min

when correcting flow remember $\sqrt{\ }$.

correct by:

Note

$^{o}C + 273 = {}^{o}K$

Ideal Gas Law equation dictates that T must be in ^{o}K.

$$Q_{corr} = \underset{\text{\& found from curve}}{Q_{measured}} \left[\left(\frac{T_2}{T_1}\right)\left(\frac{P_1}{P_2}\right)\right]^{1/2}$$

$$Q = 1.65\ \frac{m^3}{min} \bullet \left[\left(\frac{309}{297}\right)\left(\frac{762}{711}\right)\right]^{1/2}$$

$$Q = 1.74\ m^3/min$$

$$\text{TSP in } \frac{\mu g}{m^3} = \frac{\left(.1210g\right)\left(10^6\ \frac{\mu g}{g}\right)}{\left(1.74\ \frac{m^3}{min}\right)\left(24\ hrs.\right)\left(\frac{60\ min}{hr}\right)}$$

$$= 48.3\ \mu g/_{m}3 \text{ at new conditions}$$

3. a. Use visifloat curve as a transducer curve here:

$Q_{initial}$ = 60≃cfm corresponds to 1.76 m^3/min from curve

Q_{final} = 42≃cfm corresponds to 1.24 m^3/min from curve

$$\overline{Q} = \frac{1.76 + 1.24}{2} = 1.5\ m^3/min$$

Average flow reading using just initial and final readings.

$$\text{Volume of air} = (24\ hrs)(60\ \frac{min}{hr})\ (1.5\ \frac{m^3}{min}) = 2160\ m^3$$

$$\text{TSP in } \mu g/m^3 = \frac{(.255g)(10^6\ \mu g/g)}{2160\ m^3} = 118.0\ \mu g/m^3$$

	Using 2 Hour Averages			Converted to actual flows from Transducer Curve/Visifloat curve
3b.	0 - 2:	59~ ft^3/min	=	1.74 m^3/min
	2 - 4:	57≈ ft^3/min	=	1.68 m^3/min
	4 - 6:	54	=	1.59 m^3/min
	6 - 8:	49	=	1.44 m^3/min
	8 -10:	46	=	1.36 m^3/min
	10 -12:	45	=	1.32 m^3/min
	12 - 2:	44	=	1.30 m^3/min
	2 - 4:	43.5	=	1.27 m^3/min
	4 - 6:	43.5	=	1.27 m^3/min
	6 - 8:	43.5	=	1.27 m^3/min
	8 -10:	42.8	=	1.40 m^3/min
	10 -12:	42.4	=	1.38 m^3/min

$$\frac{\Sigma Q}{12} = \overline{Q} = 1.42\ \frac{m^3}{min}$$

$$V = (1440\ min)\left(1.42\ \frac{m^3}{min}\right) = 2044.8\ m^3$$

$$TSP\ in\ \mu g/m^3 = \frac{(.2550\ g)\ (10^6\ \mu g/g)}{2044.8}$$

$$= 124.7\ \mu g/m^3$$

3c. $$\%\ Error = \left(\frac{True\ Value - Measured\ Value}{True\ Value}\right) \times 100$$

$$= \left(\frac{124.7\ \mu g/m^3 - 118.0\ \mu g/m^3}{124.7\ \mu g/m^3}\right) \times 100$$

$$= 5.37\%\ error$$

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: AMBIENT REFERENCE METHODS FOR GASES

COURSE: 435 Lesson #12
LESSON TIME: 2 hours
PREPARED BY: Northrop Services, Inc. **DATE:** 2/21/79

LESSON GOAL: To develop an understanding of the principles and operation of the Reference Methods for monitoring gaseous pollutants.

LESSON OBJECTIVES:

The student will be able to:

1. Distinguish between a Reference Method or Measurement Principle and Calibration Procedure and an Equivalent Method for ambient air pollutants.
2. List the gaseous ambient pollutants now specified as criteria pollutants.
3. List the Reference Method or Measurement Principle and Calibration Procedure currently specified for each criteria pollutant.
4. Describe the operating principles of each Reference Method.

SUPPORT MATERIALS AND EQUIPMENT:

Objective Handout
Slide Projector and slides
List of Designated Reference and Equivalent Methods

12

SPECIAL INSTRUCTION: None

SELECTED REFERENCES:

Ellis, E.C., "Technical Assistance Document for the Chemiluminescence Measurement of Nitrogen Dioxide" US Environmental Protection Agency, EPA-600/4-75-003

Others given in the lesson plan.

CONTENT OUTLINE

Course: 435
Lecture Title: AMBIENT REFERENCE METHODS FOR GASES

Page 1 *of* 13

NOTES

REFERENCE AND EQUIVALENT METHODS

A. Reference Method - One specific method of analysis for a particular pollutant which is set as the standard by EPA. L12-1

B. Equivalent Method - A method which has been found experimentally accurate enough by EPA to matchanalysis specifications given for the reference methods (range, precision, sensitivity). This provides a freedom of choice for establishing monitoring networks according to Federal guidelines.

These methods (Reference and Equivalent) were chosen by the EPA after a comprehensive review of available methodologies for measuring the criteria* pollutants. Although, perhaps, not representative of "state of the art" techniques, these methods have been carefully evaluated and errors and/or interferences quantified where possible. They also represent the legal methods required by EPA for use in most federally mandated ambient monitoring. There is no difference legally in a Reference and Equivalent Method. Either may be used for monitoring, so the choice of Reference versus Equivalent should be based on other factors such as cost, availability, etc. L12-2

A Reference Method may be either manual or automated. If manual, it is a detailed chemical procedure specifying all important parameters. If automated, it consists of a measurement principle (MP) and a calibration procedure (CP). Thus for an automated method, any instrument using the measurement principle (and designated by the EPA) is a separate reference method. Among the gases, SO_2 is the only manual Reference Method...NO_2, O_3, CO, and hydrocarbons (HC) use automated methods and thus follow particular measurement principle; there are several reference methods for each. L12-3 L12-4

For a current list of the designated Reference and Equivalent Methods, contact address at top of list handed out in class. For additional information, see first page of the list.

The Federal Reference Methods (i.e., the complete description of the procedure for manual methods and the detailing of the measurement principle (MP) and calibration procedure (CP) for automated Methods) are contained in the Appendixes to 40 CFR 50

*NOTE: Criteria pollutants refer to those pollutants for which there is a national ambient air quality standard (NAAQS). The name is derived from the document which provides the criteria for selecting a particular pollutant level as the standard. These include SO_2, O_3, NO_2, CO, Hydrocarbons, TSP, and Lead.

Currrently these are:

Pollutant	Method	
Total Suspended Particulates (TSP)	Hi-Volume Sampler Manual	L12-5
Lead	Hi-Volume sampler with subsequent Atomic absorption analysis Manual	
Sulfur Dioxide (SO_2)	Pararosaniline Method Manual	L12-6
Ozone (O_3)	chemiluminescence with ethylene (MP) Ultraviolet photometry (CP) Automated	
Hydrocarbons corrected for Methane	gas chromatography with a flame ionization detector GC/FID (MP) span gases (CP) Automated	
Nitrogen Dioxide (NO_2)	Chemiluminescence with Ozone (MP) gas phase titration (GPT) of an NO standard with Ozone or NO_2 permeation device (CP) Automated	L12-7
Carbon Monoxide (CO)	Non-dispersive infra-red spectrometry (NDIR) (MP) span gases (CP) Automated	

This lecture deals only with the gaseous pollutants or the last 5 on the list so . . .

Note: It will probably prove useful to quickly review the Appendixes of 40CFR50 containing these methods before lecturing.

Sulfur Dioxide (SO_2)

Current Standard

Primary

80 $\mu g/m^3$	(0.03 ppm) -	Annual Arithmetic Mean
365 $\mu g/m^3$	(0.14 ppm) -	Maximum 24 hr. concentration not to be exceeded more than once per year

Mention that std is given for information only -- Not required to be memorized.

L12-8

Secondary

1300 $\mu g/m^3$	(0.50 ppm)	Maximum 3 hr. concentration not to be exceeded more than once per year

The Federal Reference Method for SO_2 is a Manual, wet chemical Method involving bubbling air at a controlled rate through an absorbing reagent. The exposed reagent is then chemically altered to a colored solution and the intensity of color is related to the SO_2 concentration .

L12-9 a
b
c
d

Now, to examine the reaction in more detail . . .

SO_2 is drawn through a solution of potassium tetrachloromercurate (K_2HgCl_4) also known as TCM. A reasonably stable dichlorosulfitomercurate complex ($K_2HgCl_2SO_3$) is formed. This solution of TCM + the complex is reacted with pararosaniline (tris 4-amino-phenylmethanol, $C_{19}H_{19}N_3O$) and formaldehyde (CH_2O) to form an acid (pararosaniline methyl sulfonic acid) which is intensely colored (a purplish-pink). Then a spectrophotometer is used to measure the absorbance at 548 nm.

L12-10

SO_2 + TCM $\longrightarrow$ complex

Complex + pararosaniline w/formaldehyde = Acid dye

L12-11

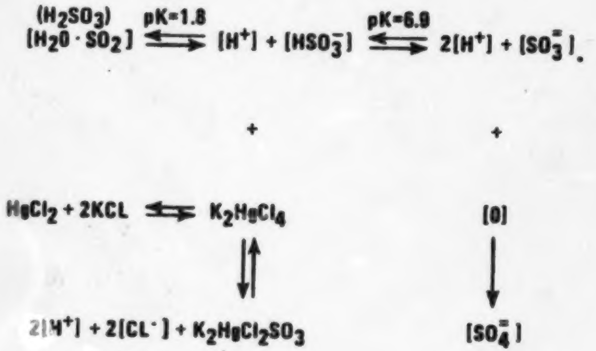
dye absorbance at 548nm is proportional to SO_2 concentration

By Beer-Lambert Relationship

A = abc
where
A = Absorbance
a = constant
b = path length
c = concentration

***NOTE: This material is somewhat technical and the level of instruction should be determined from the individual class population.

*** The following chemistry is included as information — not absolutely necessary to discuss with entire class — only interested individuals



SO$_2$ in TCM equilibrium equations.

(Improved temperature stability of sulfur dioxide samples collected by the Federal Reference Method from EPA-600/4-78-018, p.75)

In field operation, a flow controller is required — capable of measuring flow within ±2%. Can use hypodermic needles or critical orifices -- size of needles recommended is in Method -- different size (i.e., diameter and length) for different flows. Whichever is used, a membrane filter is required to prevent blockage. L12-12

The flow rate and bubble size are very important in this method and affect collection efficiency.

Flow controlled as mentioned, bubble size by using a glass impinger, 6" long with a 0.6 mm i.d. tip. Calibrate with jeweler's drills — #79 fits, #78 shouldn't. Calibration procedure is time consuming and clumsy — drills bits stick and break.

Assembled units in sample box . Point out various parts including pump, absorbers, impingers, filters, flow controller. L12-13

Calibration of the sampling train involves checking the calibration of the impinger(s), orifice(s), and total system.

L12-14

To obtain a calibration curve for the spectrophotometer — wet chemical solutions of sodium sulfite or metabisulfite can be used or alternately an SO_2 permeation tube can be used to generate required SO_2 concentrations.

spectrophotometer calibration should be checked periodically using neutral density filters

For complete calibration information, see Appendix A 40CFR50.

PROBLEMS AND ADDITIONAL CONSIDERATIONS

Most pressing problem is temperature instability

Three pertinent publications :

"Effect of Temperature on Stability of SO_2 Samples Collected by the Federal Reference Method" EPA 600/4-76-024.

L12-15

"Sulfur Dioxide Bubbler Temperature Study", EPA-600/4-76-040.

"Improved Temperature Stability of SO_2 Samples Collected by the Federal Reference Method" EPA-600/4-78-108.

Over the range of 35 to 278 µg SO_2/m^3, absorbed SO_2 is lost. Rate of decay increases five-fold for every $10^{\circ}C$ increase in temperature over range $20^{\circ}C$ to $40^{\circ}C$.

First publication gives a mathematical model that allows sample decay to be calculated if temperature history of sample is known.

Second publication evaluates 2 commercially available temperature controlled sampling boxes and gives guidance on constructing a suitable unit from a small refrigerator.

Third publication deals with chemistry of reaction and an attempt to improve absorbing solution.

All three are useful.

MINOR PROBLEMS INCLUDE:

Toxicity of TCM (Readily absorbable through skin — potential source of Mercury poisoning if mishandled). Also problem with waste disposal

Pararosaniline dye often does not meet specifications and must be purified.

Sizing of impingers — bubble size and flow rate do affect collection efficiency.

KNOWN INTERFERENTS AND CORRECTIVE ACTION

L12-16

NO_2 - Removed from TCM by treating with sulfamic acid before formaldehyde and pararosaniline are added.

Ozone (O_3) — 20 minute time delay between sampling and analysis will allow ozone to decompose.

Heavy Metals — Removed by addition of a chelating agent (ethylenediamine tetra acetic acid - EDTA)

Chelating agents merely complex or "tie up" the metals to prevent an interference

Oxidants in distilled water — Need to use high purity, freshly boiled, cooled distilled - water in preparing reagents

OZONE (O_3)

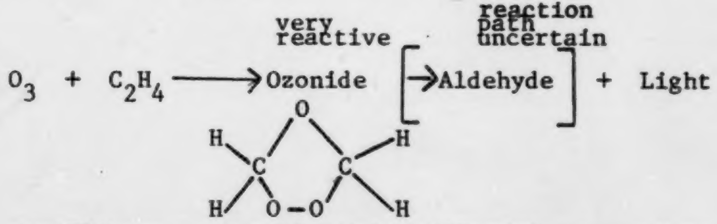
L12-17

Current Standard - Primary
0.12 ppm - hourly average with the expected number of daily exceedances not greater than one per year as averaged over the previous three year period
Secondary
Same as primary

Ozone is an automated method, therefore, it consists of a stated measurement principle and a calibration procedure.

Measurement principle is Chemiluminescence with Ethylene (C_2H_4) Chemiluminescence is merely a term describing a chemical reaction which emits light energy as a by-product. This type of principle is also used for the determination of NO_2.

L12-18



$$O_3 + C_2H_4 \longrightarrow \text{Ozonide} \left[\rightarrow \text{Aldehyde}\right] + \text{Light}$$

L12-19

The sample stream enters the analyzer and is mixed with ethylene in a reaction chamber. The light energy emitted from this reaction is then measured by a photomultiplier tube (a device converting the light energy to an electrical signal) and is related to the ozone concentration.

L12-20

The light intensity is measured by the photomultiplier tube at 420 nm. The basic reaction and principle is reasonably simple and usually operates trouble free.

A Bendix 8002 chemiluminescent Ozone monitor L12-21

The calibration of ozone monitors currently follows two choices L12-22

1. Boric acid potassium iodide (BAKI)
2. Ultraviolet photometry (UV)

UV photometry is the preferred method, but BAKI will be allowed for an *18-month phase-in period to allow labs to obtain and become familiar with the equipment required for UV photometry. The phase-in period ends on August 8, 1980** and after this date any calibration method used will have to be referenced to the UV method.

*proposed time period subject to change

**18 months from date of publication

An ozone generator, consisting of a low pressure, Mercury vapor lamp is used to produce ozone for both calibration methods. The amount of O_3 produced is a function of the oxygen content of the air stream, the irradiating energy (i.e. the intensity of the bulb) and of course the flow rate. L12-23

The specifications for a generator are given in Appendix D of 40CFR50. L12-24

U.V. PHOTOMETRY CALIBRATIONS

The air stream containing ozone is introduced into a manifold which is then sampled concurrently by the analyzer being calibrated and a UV photometer.

To calibrate with a UV photometer, several things must be done:

1. The source of zero air should be the same as the air supply being used to produce ozone.
2. An attempt should be made to determine if ozone loss is occurring in the absorption cell of the UV photometer.
3. Temperature and pressure of absorption cell should be known.

L12-25

Some other points of interest, especially in using a Dasibi O_3 monitor as a calibrator are noted in two Technical Assistance Documents (TAD's) from the Environmental Monitoring Systems Lab (EMSL) (Address is on list of designated methods). These documents deal with:

1. Technical Assistance Document for the Calibration of Ambient Ozone Monitors
2. Transfer Standards for Calibration of Ambient Air Monitoring Analyzers for Ozone

BAKI CALIBRATIONS

The Boric Acid KI technique is a modification of the neutral buffered KI (NBKI) technique that was formerly the calibration procedure. Due to inherent chemical errors, (Often resulting in errors of 15-30%) NBKI was replaced.

The stoichiometry of the reaction is:

L12-26
For students who desire it - stress that it is not required to be memorized.

$$O_3 + 2I^- + 2H^+ = I_2 + O_2 + H_2O$$

The sampling arrangement is the same as with UV photometry, with the exception that you sample concurrently with an analyzer under calibration and a BAKI sample train. This train is composed of 2 midget impingers in series filled with the BAKI absorbing reagent.

This technique is not dissimilar from the NBKI--

L12-27

1. Sample stream is bubbled through impingers (2 all glass midget impingers in series at a flow of 0.4 to 0.6 ℓ/min.).
2. Absorbance of the 2 impingers is determined with a spectrophotometer at 352 nm. This absorbance relates directly to O_3 concentration by Beer-Lambert relationship. (i.e., A calibration curve is prepared using a standard iodine solution and this plot - concentration versus absorbance - is used during the subsequent calibration).

PRECAUTIONS AND ERRORS

a. O_3 is very reactive, therefore the sampling train must be kept compact and composed of glass and teflon.

b. The absorbing reagent must be checked for the presence of reducing compounds. Procedure is contained in the Method.

If the procedure is followed carefully, errors should be reduced to ±2%. (Error value is from "Further developments in ozone calibration using Boric Acid Buffered KI", presented at 71st Annual APCA Meeting, June 25-30, 1978, by Daniel L. Flamm, Richard J. Paur, and Kenneth A. Rehme)

To return to the measurement principle (chemiluminescence with ethylene), the only identified interferent is H_2O which can cause a small positive bias. The actual reason for this bias has not been established.

L12-28

To summarize, the O_3 reference methods are based on:

L12-29

Automated Method

Measurement Principle	Calibration procedure
Chemiluminescence with Ethylene	Ultraviolet (UV) photometry or (during phase-in) Boric Acid Potassium Iodide (BAKI)

HYDROCARBONS CORRECTED FOR METHANE OR NON-METHANE HYDROCARBONS (NMHC)

L12-30

	Primary
Current Standards	160 µg/m^3 (0.24 ppm) Maximum 3 hr concentration (6-9 a.m.) not to be exceeded more than once per year.
	Secondary
	same as primary

NOTE: The standard for NMHC is designed for use as a guide in devising State Implementation Plans (SIPs) to achieve the ozone standard. It does not mean that hydrocarbons as a class are a health or welfare hazard (although obviously some - benzene, etc., are problems)

AUTOMATED METHOD

Measurement principle is gas chromatography using a Flame Ionization Detector (FID) L12-31

Calibration procedure involves using a series of calibration gases.

Gas chromatography is a technique which allows for separation of compounds. The hydrocarbons are thus separated and then burned or ionized in a hydrogen flame. The flame is the heart of the FID. Most commonly, the procedure is as follows: L12-32

1. 1st Cycle - Determination of total Hydrocarbons. All hydrocarbons in the sampled air including methane are burned in the flame and detected. This signal is stored as total hydrocarbons.

2. 2nd Cycle - Sample is passed over a stripper column which removes CO_2, H_2O, HC heavier than CH_4. Air leaving column contains only CO + CH_4.
3. CO, CH_4 mixture proceeds to an analytical column where they are separated.
4. CH_4 then goes through a methanator column which causes no change in the methane. It then goes to the FID where the methane is measured and the signal is stored.
5. The CO follows the methane through the methanator and is reduced to methane. It then leaves as methane to the FID where it is measured and the signal is stored as CO.
6. The stripper column is back flushed to clean the column to prevent FID contamination.
7. The non methane total Hydrocarbon Concentration is determined manually or electronically by subtracting Methane Concentration (signal) from the total Hydrocarbon Concentration (signal).

The CO measurements are not sensitive enough to allow their use for ambient monitoring. They can be used for relative values, however.

The Beckman 6800 Air Quality Chromatograph is an example of this technique. As can be seen, this method involves valving and switching of flows. There are problems (leaks, sticking valves, etc.) that need to be carefully checked. L12-33

CALIBRATION

The Federal Register Calibration procedure requires that various concentrations of Methane be used. L12-34

PROBLEMS AND ERRORS

The sampling for ambient levels of NMHC by the Federal Reference Method has many difficulties. We will discuss some of the more significant.

1. The FID has a non-linear response to increasing number of carbons in hydrocarbons. In general, the response decreases with increasing number of carbon atoms. Also, response can vary depending on the chemical structure (type bonds and bond placement) L12-35

2. GC columns and FID have individual response characteristics. They are not interchangeable. L12-36

3. The detector cell is temperature sensitive. Must be insulated. L12-37

4. Span drift may exceed EPA specifications (±5% for 24 hours) L12-38

5. Atmospheric moisture content appears to affect measurements. L12-39

6. Poor accuracy at concentrations near NAAQS.

For further discussion of errors with this method see:

"Evaluation of the EPA Reference Method for the Measurement of Non-Methane Hydrocarbons - Final Report" EPA-600/4-77-033. L12-40

Further developmental work is being done to revise this method, and caution is advised in its application.

NITROGEN DIOXIDE L12-41

Primary Standard: .05 ppm or 100 $\mu g/m^3$ Annual arithmetic mean.

Secondary Standard: Same as primary standard

Ambient air contains both nitric oxide (NO) and nitrogen dioxide (NO_2). The measurement principle for nitrogen dioxide requires that nitrogen dioxide first be converted to nitric oxide and then using the measurement principle of the chemiluminescence resulting from the reaction of nitric oxide with ozone to indirectly measure the concentration of nitrogen dioxide. L12-42

$$NO + O_3 \longrightarrow NO_2^* + O_2$$

$$NO_2^* \longrightarrow NO_2 + h\nu$$

The light, thus produced, passes through an optical filter that isolates a given spectral region and strikes a photomultiplier (PM) tube. The intensity of the emission is directly related to the concentration of NO. L12-43

Nitric Oxide is measured directly. Total oxides of nitrogen measurements are made by catalytic conversion of nitrogen dioxide to nitric oxide by a carbon base and/or other metal converter resulting in a total oxide of nitrogen concentration ($NO_x = NO + NO_2$). The difference between total oxides of nitrogen ($NO_2 + NO$) and nitric oxide is a measure of nitrogen dioxide concentration.

CALIBRATION: L12-44

There are two methods designated for the calibration of a $NO - NO_x - NO_2$ analyzer. The first method involves the rapid Gas Phase Titration of an NO standard with O_3. This produces a known amount of NO_2 which is used to calibrate the NO_2 channel of the instrument. L12-45

$$NO + O_3 \longrightarrow NO_2 + O_2$$ L12-46

To obtain stoichiometric quantities of NO_2, the residence time, the time allowed for the reaction to occur, is critical and specifications for the reaction chamber, flow rates, etc., are given in Appendix F of 40CFR50. L12-47

The other method for the calibration of the NO_2 channel is by the use of a NO_2 permeation tube with a dilution system. The NO_2 produced from the permeation system is diluted with zero air to produce known concentrations of NO_2. This is used to calibrate the NO_2 channel of the instrument. L12-48

This was discussed thoroughly in a previous lecture.

An NO standard in combination with a dilution system is used to calibrate the NO and NO_x channels of an $NO - NO_x - NO_2$ instrument.

An excellent document for use in the calibration of these instruments is "Technical Assistant Document for the Chemiluminescence Measurement of Nitrogen Dioxide", US Environmental Protection Agency, EPA-600/4-75-003. L12-49

CARBON MONOXIDE

Primary Standard: 1 hour standard = 35 ppm (40 mg/m^3) L12-50
8 hour standard = 9 ppm (10 mg/m^3)
not to exceed more than once a year

Secondary Standard: Same as primary standards

The Measurement Principle for determining carbon monoxide is non-dispersive infrared spectrometry. L12-51

Infrared light passes through the sample and reference cells and then passes through a bandpass filter which limits the wavelengths of light entering the detector cell. The reference cell is filled with a non-absorbing inert gas such as argon or nitrogen. If no pollutant gas is present in the sample cell, the amount of radiation reaching the reference half and the sample half of the detector cell L12-52a will be equal; therefore, the temperature (and resulting pressure) of both halves of the detector will be equal. As pollutant gas enters the sample cell, the energy reaching the sample half of the detector will be less, due to the absorption of some of the infrared light by CO. The temperature (and resulting pressure) is lowered on the sample side of the detector cell facilitating a distention in the diaphragm (the pressure is directly related to the temperature of a gas at a constant volume.) The distention of the diaphragm produces a capacitance change that is converted to a voltage output by the instrument. The optical chopper serves to create an alternating current (ac) signal which can easily be amplified.

L12-52b

This technique as described thus far suffers from interferences due
to broad band absorption of carbon dioxide, water vapor, and
hydrocarbons. When these interferents are present, the NDIR would
yield a higher concentration of CO than was actually present. If L12-53
the detector cells are arranged in series rather than in parallel,
the distention of the diaphragm is the result of the differential
absorption of CO in the front and rear chambers and these inter- L12-54
ferences are minimized. Calibration of NDIR instruments is
accomplished by simple dilution of concentrated cylinder gases.

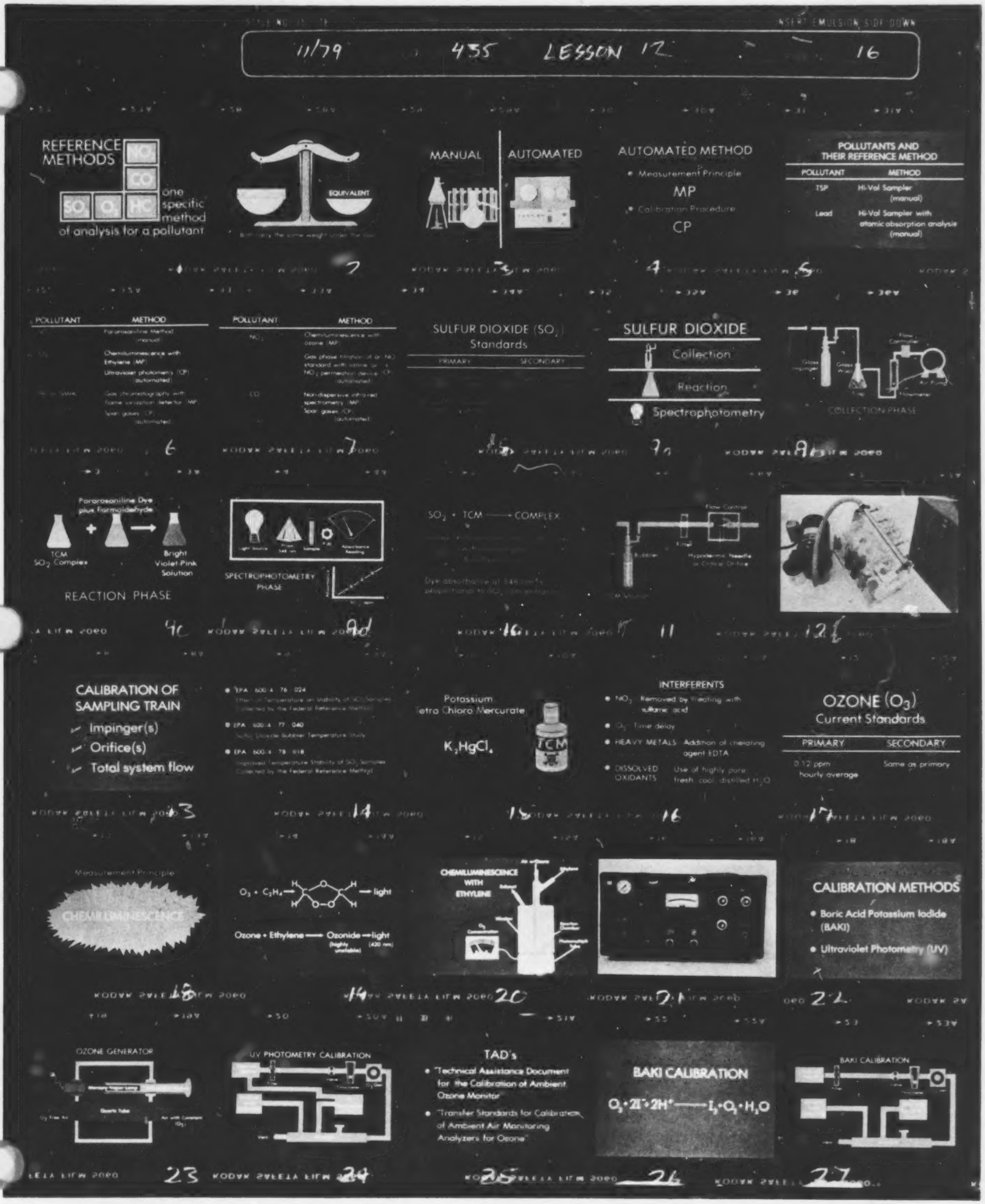
Review:

L12-55

Reference Methods vs Equivalent Methods

L12-56

Criteria gaseous pollutants and Reference Methods for each. L12-57



11/79 455 LESSON 12 16

REFERENCE METHODS
NO_2 CO SO_2 O_3 HC
one specific method of analysis for a pollutant

EQUIVALENT
Both carry the same weight under the law

2

MANUAL | AUTOMATED

3

AUTOMATED METHOD
- Measurement Principle
MP
- Calibration Procedure
CP

4

POLLUTANTS AND THEIR REFERENCE METHOD

POLLUTANT	METHOD
TSP	Hi-Vol Sampler (manual)
Lead	Hi-Vol Sampler with atomic absorption analysis (manual)

5

POLLUTANT	METHOD
[illegible]	Pararosaniline Method (manual)
[illegible]	Chemiluminescence with Ethylene (MP) Ultraviolet photometry (CP) (automated)
[illegible]	Gas chromatography with flame ionization detector (MP) Span gases (CP) (automated)

6

POLLUTANT	METHOD
NO_2	Chemiluminescence with ozone (MP) Gas phase titration of an NO standard with ozone or a NO_2 permeation device (CP) (automated)
CO	Non-dispersive infrared spectrometry (MP) Span gases (CP) (automated)

7

SULFUR DIOXIDE (SO_2) Standards

PRIMARY	SECONDARY

SULFUR DIOXIDE
Collection
Reaction
Spectrophotometry

9a

Flow Controller
Glass Impinger
Glass Wool
Trap
Air Pump
Flowmeter
COLLECTION PHASE

9b

Pararosaniline Dye plus Formaldehyde
TCM SO_2 Complex
Bright Violet-Pink Solution
REACTION PHASE

9c

Light Source
Prism 548 nm
Sample
Absorbance Reading
SPECTROPHOTOMETRY PHASE

9d

SO_2 + TCM → COMPLEX

Dye absorbance at 548 nm is proportional to SO_2 concentration

10

Flow Control
Bubbler
Filter
Hypodermic Needle or Critical Orifice

11

12

CALIBRATION OF SAMPLING TRAIN
- ✓ Impinger(s)
- ✓ Orifice(s)
- ✓ Total system flow

13

- EPA 600/4-76-024 Effect of Temperature on Stability of SO_2 Samples Collected by the Federal Reference Method
- EPA 600/4-77-040 Sulfur Dioxide Bubbler Temperature Study
- EPA 600/4-78-018 Improved Temperature Stability of SO_2 Samples Collected by the Federal Reference Method

14

Potassium Tetra Chloro Mercurate
K_2HgCl_4
TCM

15

INTERFERENTS
- NO_2 Removed by treating with sulfamic acid
- O_3 Time delay
- HEAVY METALS Addition of chelating agent EDTA
- DISSOLVED OXIDANTS Use of highly pure fresh, cool, distilled H_2O

16

OZONE (O_3) Current Standards

PRIMARY	SECONDARY
0.12 ppm hourly average	Same as primary

17

Measurement Principle
CHEMILUMINESCENCE

18

O_3 + C_2H_4 → ozonide → light
Ozone + Ethylene → Ozonide → light
(highly unstable) (420 nm)

19

CHEMILUMINESCENCE WITH ETHYLENE
Air w/Ozone
Ethylene
Exhaust
O_3 Concentration

20

21

CALIBRATION METHODS
- Boric Acid Potassium Iodide (BAKI)
- Ultraviolet Photometry (UV)

22

OZONE GENERATOR
Mercury Vapor Lamp
Quartz Tube
O_3 Free Air
Air with Constant (O_3)

23

UV PHOTOMETRY CALIBRATION
O_3 Gen
Vent

24

TAD's
- "Technical Assistance Document for the Calibration of Ambient Ozone Monitor"
- "Transfer Standards for Calibration of Ambient Air Monitoring Analyzers for Ozone"

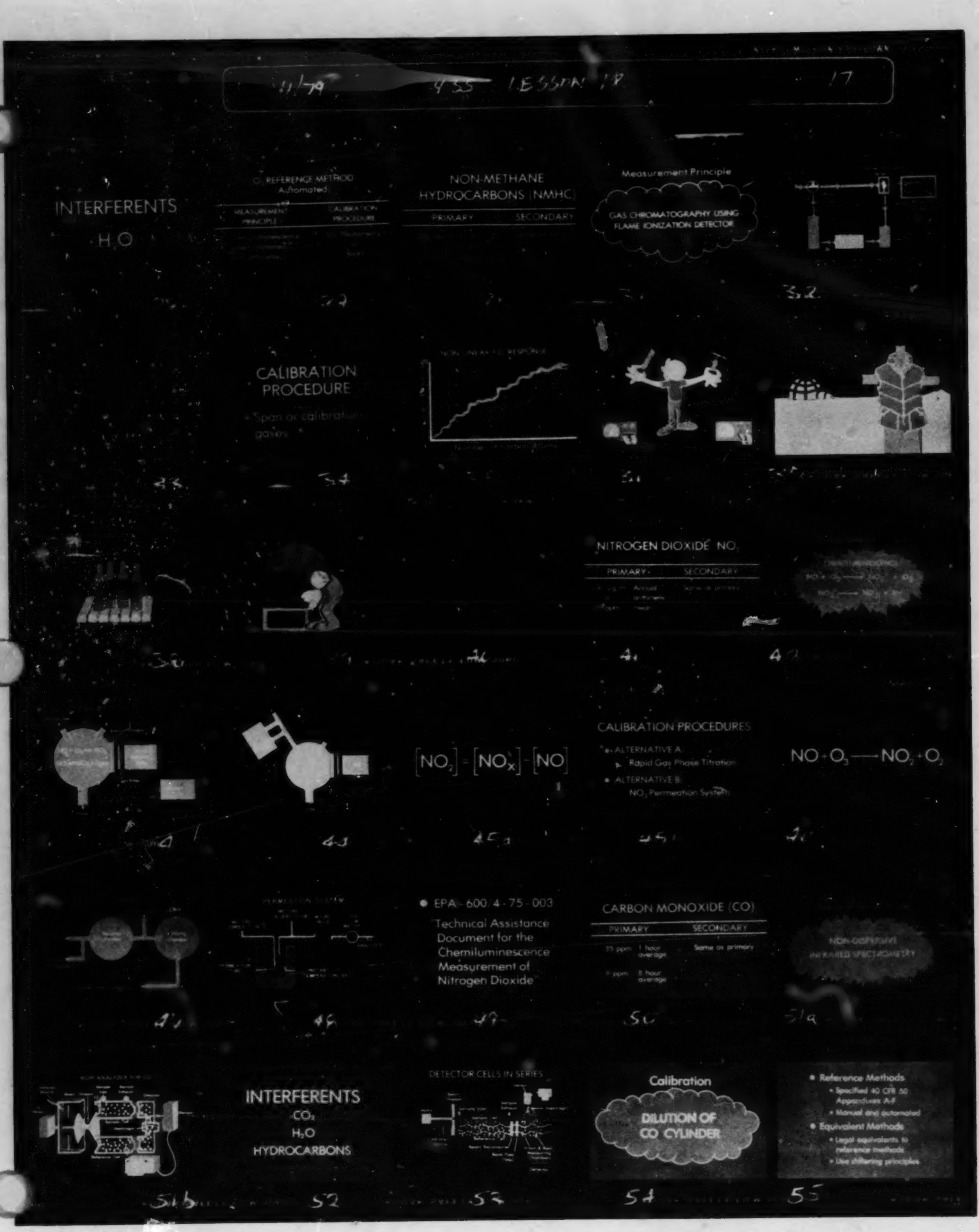
25

BAKI CALIBRATION
$O_3 + 2I^- + 2H^+ \longrightarrow I_2 + O_2 + H_2O$

26

BAKI CALIBRATION

27



11/79 435 LESSON 18 17

INTERFERENTS

H_2O

O_3 REFERENCE METHOD (Automated)

MEASUREMENT PRINCIPLE	CALIBRATION PROCEDURE

NON-METHANE HYDROCARBONS (NMHC)

PRIMARY	SECONDARY

Measurement Principle

GAS CHROMATOGRAPHY USING FLAME IONIZATION DETECTOR

32

CALIBRATION PROCEDURE

- Span or calibration gases

34

NITROGEN DIOXIDE NO_2

PRIMARY	SECONDARY
Annual arithmetic mean	Same as primary

$[NO_2] = [NO_x] - [NO]$

CALIBRATION PROCEDURES

- ALTERNATIVE A:
  - Rapid Gas Phase Titration
- ALTERNATIVE B:
  - NO_2 Permeation System

$NO + O_3 \longrightarrow NO_2 + O_2$

43 45a 45b

- EPA-600/4-75-003

"Technical Assistance Document for the Chemiluminescence Measurement of Nitrogen Dioxide"

CARBON MONOXIDE (CO)

PRIMARY		SECONDARY
35 ppm	1 hour average	Same as primary
9 ppm	8 hour average	

NON-DISPERSIVE INFRARED SPECTROMETRY

47 48 49 50 51a

INTERFERENTS

CO_2

H_2O

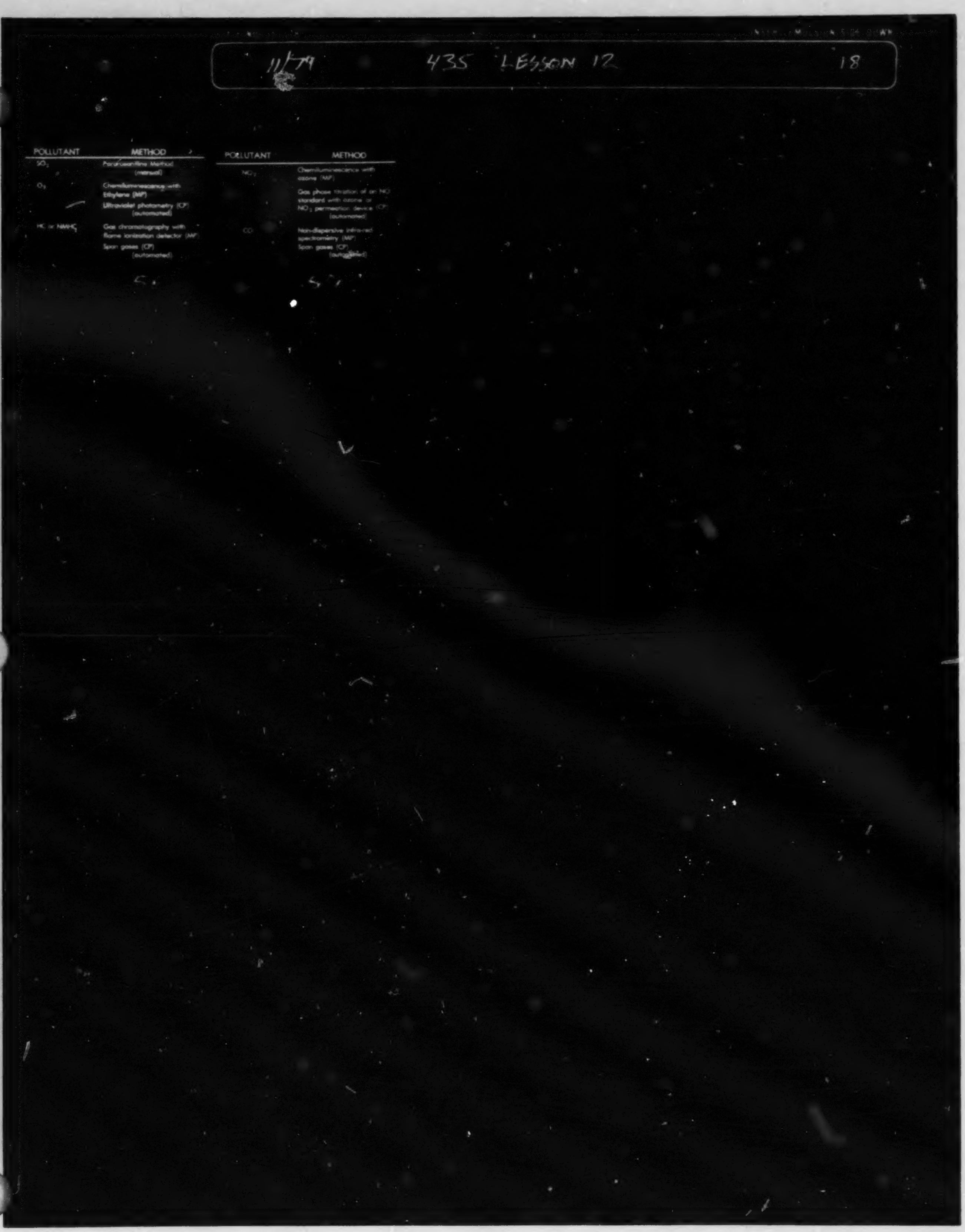
HYDROCARBONS

Calibration

DILUTION OF CO CYLINDER

- Reference Methods
  - Specified 40 CFR 50 Appendices A-F
  - Manual and automated
- Equivalent Methods
  - Legal equivalents to reference methods
  - Use differing principles

51b 52 53 54 55



11/79 435 LESSON 12 18

POLLUTANT	METHOD
SO_2	Pararosaniline Method (manual)
O_3	Chemiluminescence with Ethylene (MP) Ultraviolet photometry (CP) (automated)
HC or NMHC	Gas chromatography with flame ionization detector (MP) Span gases (CP) (automated)

POLLUTANT	METHOD
NO_2	Chemiluminescence with ozone (MP) Gas phase titration of an NO standard with ozone or NO_2 permeation device (CP) (automated)
CO	Non-dispersive infra-red spectrometry (MP) Span gases (CP) (automated)

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: SURVEILLANCE NETWORKS

COURSE: 435 - Lesson #13
LESSON TIME: 45 min.
PREPARED BY: DATE: 2/15/79

Northrop Services, Inc.

LESSON GOAL:	Familiarize the students with the status of ambient air monitoring regulations pertaining to surveillance networks and the requirements of such a network, including its major subsystems. This lecture overlaps the lecture that follows on Site Selection.
LESSON OBJECTIVES:	The student will be able to: Describe the need to specify the objectives of sampling tied to intended use of the data as the first step in designing the network. Cite the major sources of EPA guidance on monitor siting. Discuss the composition of SAMWG and the status of its recommendations. Defend the need for a quality assurance program. Describe an ambient monitoring network including its major subsystems.
SUPPORT MATERIAL AND EQUIPMENT:	Objective handout Slide projector with tray
SPECIAL INSTRUCTIONS:	Students have been away from lecture for a day now, and need to be returned to note taking. Keep lecture moving and light, while watching feedback to insure attention. This lecture also ties in with the next lecture on site selection. Read that lesson plan before giving this lecture. Remember, a week has been spent dealing with specific points. This lecture summarizes rapidly and gives a loose framework capable of being used with any size network.

SELECTED REFERENCES:

"Air Monitoring Strategy for State Implementation Plans" EPA-450/2-77-010, June, 1977.

"Quality Assurance Handbook for Air Pollution Measurement Systems", Vol. I - Principles, EPA-600/9-76-005, March 1976.

"Quality Assurance Handbook for Air Pollution Measurement Systems", Vol. II - Ambient Air Specific Methods, EPA-600/4-77-027a, May 1977.

Title 40 Code of Federal Regulations Part 58 (May 10, 1979).

CONTENT OUTLINE

Course: 435 - Lesson #13
Lecture Title: SURVEILLANCE NETWORKS

Page 1 of 6

NOTES

INTRODUCTION

Before starting into network design, first some background information about EPA efforts.

To critically review and evaluate current air monitoring activities, the Standing Air Monitoring Work Group was formed in October 1975. This group was composed of state and local air pollution control agencies in conjunction with regional and program offices of the EPA. L13-1

MAJOR FINDINGS L13-2a

(1) Too few monitors in some locations, too many in others L13-2b

(2) Data produced of unknown quality -- poor quality assurance programs L13-2c L13-2d

(3) Lack of coordination of monitoring activities L13-2e

(4) SIP network regulations too inflexible (for others see pp. 2-3 of Air Monitoring Strategy for State Implementation Plans, EPA 450/2-77-010)

To correct these, several steps were taken, most important of which are: L13-3

(1) A complete revision of nearly all of the ambient air monitoring regulations with the intent to
  (a) Improve data quality,
  quality assurance,
  siting, and,
  methodology
  (b) Improve the timely submittal of data
  (c) Improve the cost effectiveness of monitoring
  (d) Improve monitoring program's responsiveness to data needs

(2) This reorganization was promulgated in the Federal Register on May 10, 1979 and detailed the requirements for: L13-4
  (a) A minimum quality assurance plan
  (b) Network design and periodic reevaluation of monitoring network
  (c) Methodology
  (d) Siting - instrument and probe
  (e) Data reporting

The majority of these regulations, among others, are part of 40 CFR 58 with seven (7) appendixes.

Formerly in
40 CFR 50
40 CFR 51
40 CFR 53

I. Regulations

(Explain briefly Federal System of publishing regulations)

A. Code of Federal Regulations--yearly summary (July 1 - June 30) of all Federal Regs, then supplemented with daily Federal Register publications.

B. 3 types of monitoring stations are defined.

SLAMS - State and Local Air Monitoring Stations (required for SIP networks)
NAMS - National Air Monitoring Stations (required for SIP networks)
SPMS - Special Purpose Monitoring Stations (optional)

This regulatory reorganization now makes it easier to understand and find EPA ambient monitoring regulations.

II. Network Design

A. Network can be divided (arbitrarily) into 2 major systems

- Sensor System
- Data System

B. PRELIMINARY PLANNING must be done first

1. First step should always be to define the purpose of the program and the uses for the data.
    a. Most important - emphasize need to carefully accomplish this step.
    b. Hopefully, if this design process is done carefully, we'll minimize expense while meeting program needs. This step also is used in siting monitors as will be discussed in the next lecture.
2. After identifying the purpose of the network, we can assemble background materials on:
    a. Meteorology
    b. Topography
    c. Source characteristics affecting area of interest
    d. Legal and administrative concerns

NOTES

L13-5

L13-6

Throughout design process, illustrate steps with examples from your own experience

L13-7

Ask students to name some typical ones (see siting lecture for 12 SO_2 uses)

L13-8

Appendixes of SO_2 siting manual (EPA-450/3-77-013) have some sources of background materials

CONTENT OUTLINE

Course: 435 - Lesson #13
Lecture Title: SURVEILLANCE NETWORKS

NOTES

C. This background material will provide the basis for decisions that must be made during the DESIGN PROCESS

1. SENSOR SYSTEM — L13-9

   Need to answer several questions — L13-10a

   - What to monitor
   - How to monitor
   - Where to monitor
   - Maintenance and calibration needs

   a. What to Monitor — L13-10b

      (1) Determined from needs of program, could be:

      - legal standards
      - expected problems
      - PSD or background

      (2) Need to specify what will be monitored and if more than one specie involved

   b. How to Monitor — L13-10c

      (1) May be specified by regulations

      (2) Often reference or equivalent methods - EPA — L13-11

      good time to review reference methods

      TSP - Hi-volume method
      CO - Non-dispersive infrared
      NMHC - GC with flame ionization detector
      O_3 - Chemiluminescence with ethylene
      NO_2 - Chemiluminescence with ozone
      SO_2 - Pararosaniline
      Lead - Hi-vol w/atomic absorption

      (3) Other standard methods

      ASTM, NIOSH, or others + literature Searches

   c. Where to Monitor

      (1) Will come in detail in the next lecture — L13-10d

      (2) EPA has issued a reasonable amount of guidance in this area, includes probe locations

d. Maintenance and calibration needs are difficult to estimate -- include here manpower, equipment, parts, etc.

L13-10e

- sources of information

(a) Manufacturer's recommendations tend to be optimistic

(b) Other users
can obtain names from equipment manufacturers or state agencies

(c) In-house records or former experience

This completes the sensor design and the first half of the Network. Next deal with design of the Data System.

2. DATA SYSTEM

L13-12

Composed of 2 subsystems:

- recording and transmission
- data handling

a. Recording and Transmission

L13-13

(1) Recording

(a) handle an electrical signal from an instrument or record a reading from a manual analysis. Must decide if need requires a machine readable format for computer handling.

"rule of thumb"

(b) Difficult to decide - process is dependent on individual system - each unique.

(c) Roughly, if more than 1 man week/month is required in data handling, may be more cost effective to use some automated processing.

L13-14

(d) Can seek help from computer system engineers

(2) Transmission

(a) How fast do you need data -- don't overemphasize and use telemetry if data is for a quarterly report.

(b) Automated data loggers coupled with telemetered lines take time to debug -- include this in network cost.

(c) Make as simple, cheap and uncomplicated as possible.

(d) Eventually move data to a central processing or handling facility.

b. Data Handling

Having recorded data and transmitted it to a central unit, can now design data handling subsystem -- involves formating, validating, analyzing, storing and retrieving data.

L13-15a

(1) Format - basically just a systematic listing

(a) should be:

- clean and understandable
- well documented
- suitable for interchange
- available

(b) Might consider SAROAD Format - developed by EPA for use with the National Air Data Bank. A convenient format suitable for use to EPA and states has already been de-bugged.

L13-16
SAROAD - storage and retrieval of aerometric data

(c) Need to consider if different data users (i.e. EPA, internal, etc.) can use same format

(2) Validation - should be performed by an Air Pollution professional with intimate knowledge of the sensor and data systems, as well as any peculiarities of the air pollution problem in the area. The validator should be:

L13-15b

- officially designated
- check abnormal values and rapid changes
- make corrections where possible

(This function is extremely important and reflects the major deficiency noted by SAMWG.)

For guidance on this and other areas of quality assurance see:

L13-17

"Quality Assurance Handbook for Air Pollution Measurement Systems" Volumes I and II.

Vol. I. EPA-600/9-76-005
Vol. II. EPA-600/4-77-027a

Both are valuable aids in designing an effective quality assurance program.

(3) Analysis - possibly consult a professional statistician familiar with Air Pollution data; use of data will probably dictate appropriate statistics

L13-15c

Log - normal distributions for long-term trends, various types of means, not complete consensus among "experts", can consult EPA.

L13-18

Monitoring and Data Analysis Division (MDAD)
US EPA/MD-14
Research Triangle Park, N.C. 27711

(4) Storage

L13-15d

- (a) secure - possible legal requirement
- (b) systematic - easily comparable year to year
- (c) protective - prevent physical deterioration
  thermally sensitive
  magnetic or electric interference
- (d) accessible - to proper personnel

(5) Retrieval

L13-15e

- (a) easily located
- (b) secure

(6) Reporting

- (a) State Implementation Plan (SIP) monitoring networks are required to report data collected before January 1, 1981 from all stations on a quarterly basis to EPA.

L13-15f

- (b) For data collected after January 1, 1981:
  - (1) NAMS data must be submitted quarterly
  - (2) A SLAMS data summary report must be submitted annually

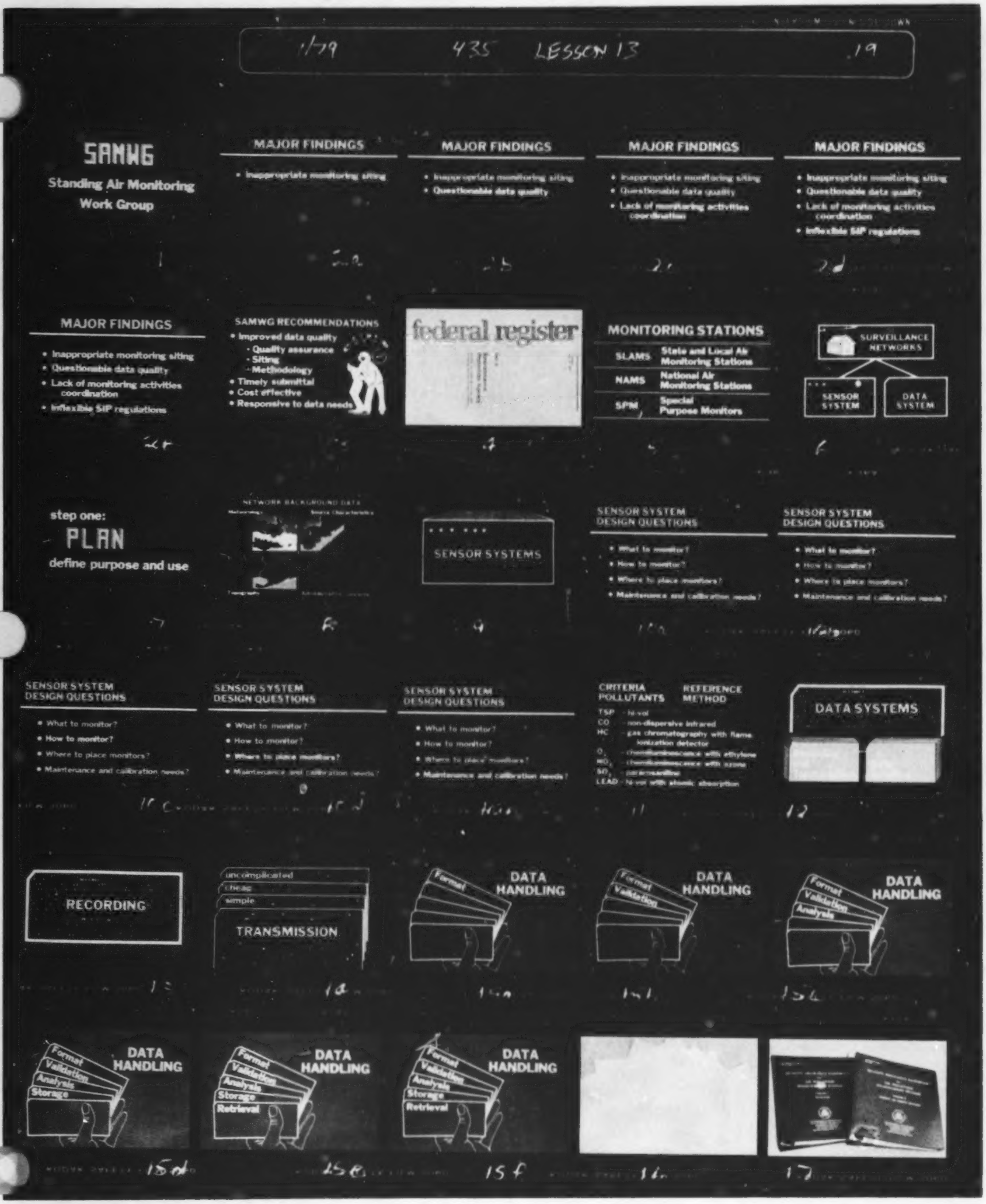
Have covered design of Data System

L13-15g

Combine Sensor and Data System for total Network

Summarize material

Time spent on summary is dependent on class attention. Use instructor discretion.



1/79 435 LESSON 13 .19

SAMWG

Standing Air Monitoring Work Group

1

MAJOR FINDINGS

- Inappropriate monitoring siting

2a

MAJOR FINDINGS

- Inappropriate monitoring siting
- Questionable data quality

2b

MAJOR FINDINGS

- Inappropriate monitoring siting
- Questionable data quality
- Lack of monitoring activities coordination

2c

MAJOR FINDINGS

- Inappropriate monitoring siting
- Questionable data quality
- Lack of monitoring activities coordination
- Inflexible SIP regulations

2d

MAJOR FINDINGS

- Inappropriate monitoring siting
- Questionable data quality
- Lack of monitoring activities coordination
- Inflexible SIP regulations

2e

SAMWG RECOMMENDATIONS

- Improved data quality
  - Quality assurance
  - Siting
  - Methodology
- Timely submittal
- Cost effective
- Responsive to data needs

3

federal register

4

MONITORING STATIONS

SLAMS	State and Local Air Monitoring Stations
NAMS	National Air Monitoring Stations
SPM	Special Purpose Monitors

5

SURVEILLANCE NETWORKS

SENSOR SYSTEM

DATA SYSTEM

6

step one:

PLAN

define purpose and use

7

NETWORK BACKGROUND DATA

8

SENSOR SYSTEMS

9

SENSOR SYSTEM DESIGN QUESTIONS

- What to monitor?
- How to monitor?
- Where to place monitors?
- Maintenance and calibration needs?

10a

SENSOR SYSTEM DESIGN QUESTIONS

- **What to monitor?**
- How to monitor?
- Where to place monitors?
- Maintenance and calibration needs?

10b

SENSOR SYSTEM DESIGN QUESTIONS

- What to monitor?
- **How to monitor?**
- Where to place monitors?
- Maintenance and calibration needs?

10c

SENSOR SYSTEM DESIGN QUESTIONS

- What to monitor?
- How to monitor?
- **Where to place monitors?**
- Maintenance and calibration needs?

10d

SENSOR SYSTEM DESIGN QUESTIONS

- What to monitor?
- How to monitor?
- Where to place monitors?
- **Maintenance and calibration needs?**

10e

CRITERIA POLLUTANTS	REFERENCE METHOD
TSP	hi-vol
CO	non-dispersive infrared
HC	gas chromatography with flame ionization detector
O_3	chemiluminescence with ethylene
NO_2	chemiluminescence with ozone
SO_2	pararosaniline
LEAD	hi-vol with atomic absorption

11

DATA SYSTEMS

12

RECORDING

13

uncomplicated

cheap

simple

TRANSMISSION

14

DATA HANDLING

Format

15a

DATA HANDLING

Format

Validation

15b

DATA HANDLING

Format

Validation

Analysis

15c

DATA HANDLING

Format

Validation

Analysis

Storage

15d

DATA HANDLING

Format

Validation

Analysis

Storage

Retrieval

15e

DATA HANDLING

Format

Validation

Analysis

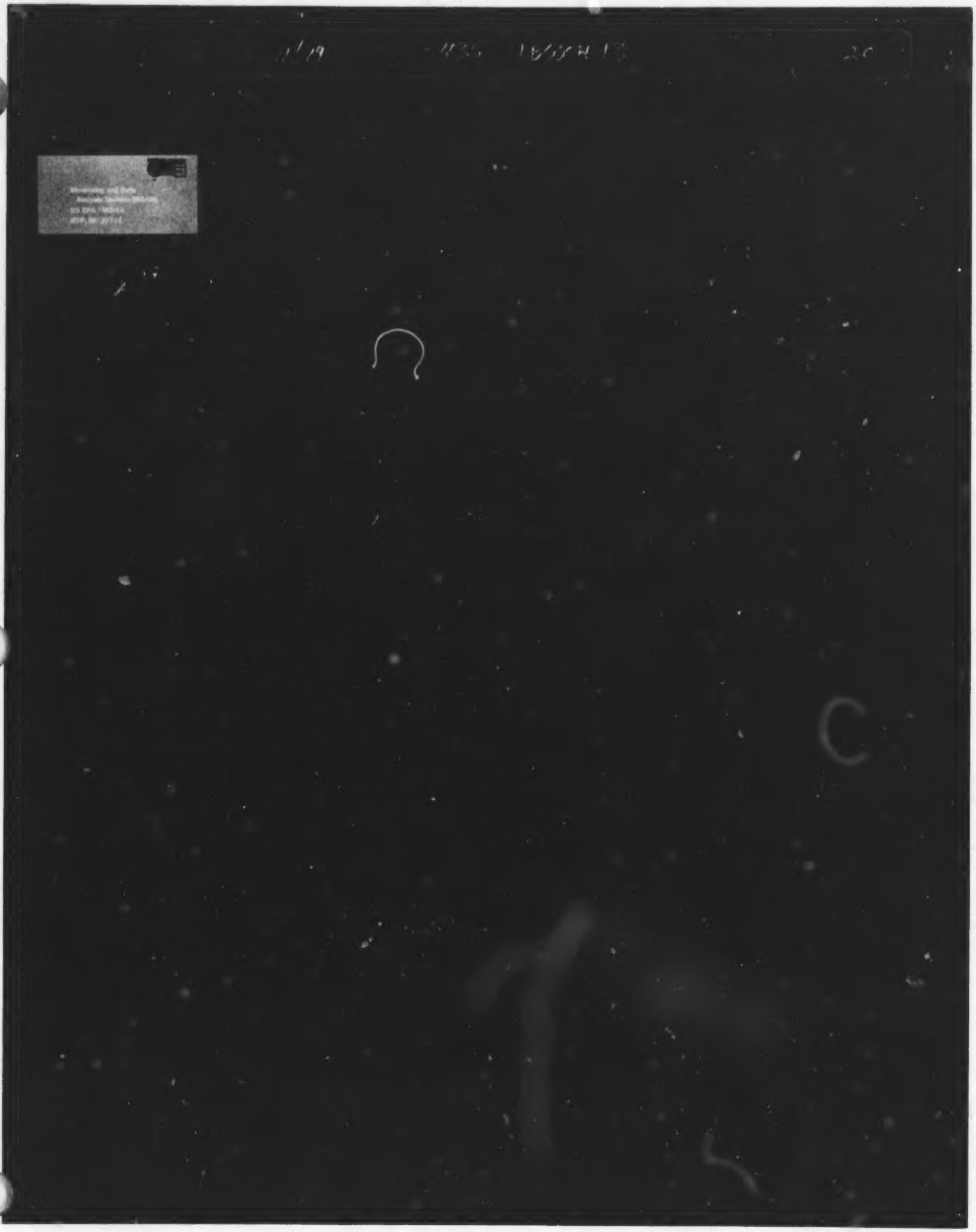
Storage

Retrieval

15f

16

17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20

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: SITE SELECTION

COURSE: 435 - Lesson #14
LESSON TIME: 45 Min.
PREPARED BY: Northrop Services, Inc. **DATE:** 2/22/79

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

LESSON GOAL: Familiarize students with location of EPA siting regulations and guidance. Briefly outline procedure used in EPA siting documents and discuss its utility, and to give a basic understanding of some of the important factors involved in correctly siting ambient air quality monitors.

LESSON OBJECTIVES:

The student will be able to:

Discuss the need to properly site pollutant monitors

Locate the documents for guidance on siting pollutant monitors

Outline the procedure used to site monitors as described in the guidance documents.

Locate regulations associated with monitor siting

Recognize factors involved in selecting proper siting of monitors.

SUPPORT MATERIAL AND EQUIPMENT:

1. Handout of p.31 of SO_2 siting manual
2. Objective handout
3. Slide projector w/tray
4. EPA-450/3-77-013 "Optimum Site Exposure Criteria For SO_2 Monitoring"

14

SPECIAL INSTRUCTIONS:
This lecture is presented near the end of the course - students' attention span and motivation are typically reduced (concerned about Final, returning to work, etc.) Attempt to be light and watch feedback from students to maintain attention. Material is important!!

SELECTED REFERENCES:

"Selecting Sites for Carbon Monoxide Monitoring", EPA-450/3-75-077, Sept. 1975.

"Optimum Site Exposure Criteria for SO_2 Monitoring", EPA-450/3-77-013, April, 1977.

"Selecting Sites for Monitoring Total Suspended Particulates", EPA-450/3-77-018, June 1977.

"Site Selection for the Monitoring of Photochemical Air Pollutants" EPA-450/3-78-013, April 1978.

"Guidance for Air Quality Monitoring Network Design and Instrument Siting (revised)", OAQPS 1.2-012, Sept 1975.

40CFR58 Appendixes D and E

AIR POLLUTION TRAINING INSTITUTE

CONTENT OUTLINE

Course 435 Lesson #14
Lecture Title: SITE SELECTION

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Page 1 of 6

NOTES

INTRODUCTION: Review of available siting guidance — TITLE SLIDE

OAQPS 1.2-012 "Guidance for Air Quality Monitoring Network Design and Instrument Siting" (Revised Sept. 1975.)

OAQPS (Office of Air Quality Planning and Standards) is responsible for setting standards and methods among other things--they have published a series of guideline documents in these areas... The above is most current.

Material is somewhat outdated, superseded by the individual siting documents, 1.2-012 has 2 appendixes, CO Siting and Monitoring around Large Point Sources. Both are also of limited utility. 1.2-012 is mentioned mainly to avoid future confusion if someone should locate it later. It does contain some useful information, yet you must be careful in using it.

Next, the 4 Siting Documents. . . — L14-1

"Selecting Sites for Carbon Monoxide Monitoring" EPA-450/3-75-077, Sept. 1975.

"Optimum Site Exposure Criteria for SO_2 Monitoring" EPA-450/3-77-013, April 1977.

"Selecting Sites for Monitoring Total Suspended Particulates" EPA-450/3-77-018, June 1977.

"Site Selection for the Monitoring of Photochemical Air Pollutants", EPA-450/3-78-013, April 1978.

These were done under contract to EPA and all 4 utilize the same approach.

This approach basically is as follows:

1. Define purpose of site or need for data — L14-2
2. Assemble background information and site selection aids — L14-3
3. Define the general siting area accounting for chemical and meteorological individualities — L14-4
4. Establish the final site characteristics including probe height and location — L14-5

The guidance contained in these documents is consistent with the regulations for ambient air monitoring contained in 40CFR58 plus its appendixes.

CONTENT OUTLINE

Course: 435 - Lesson #14
Lecture Title: SITE SELECTION

NOTES

In terms of completeness and understandability, the SO_2 document is the best, so if you intend to obtain only one, the SO_2 should be it.

Once familiar with the approach, it will be easier to assimilate the material in the others.

[To further the process, we will go through a set of examples from the SO_2 document - see handout of p. 31.]

your copy can be found in Appendix A page 245.

*Before beginning, a note of caution: There are no instant siting "experts". Properly siting a monitor involves correlating diverse pieces of information and making compromises where necessary. If students are interested in further information, see references or consider APTI Course 463 "Ambient Air Monitoring Systems"

I. Define the purpose or need for monitoring L14-6

A. This is the first step - omitting it can be fatal to successful siting - Note on chart that this is after assembling background aids. Chart should be reversed or steps done concurrently.

Now for SO_2, some of the major data uses are:

1. Judging attainment of SO_2 NAAQS.
2. Evaluating progress in achieving/maintaining the NAAQS or state/local standards. L14-7
3. Developing or revising state implementation plans (SIPs) to attain/maintain NAAQS; evaluating control strategies.
4. Reviewing new sources. L14-8
5. Establishing baseline air quality levels for preventing significant deterioration (PSD) and for air quality maintenance planning (AQMP).
6. Developing or revising national SO_2 control policies [e.g., new source performance standards (NSPS), tall stacks, supplementary control systems (SCS)].
7. Providing data for model development and validation. L14-9
8. Providing data to implement the provisions of the Energy Supply and Environmental Coordination Act (ESECA) of 1974.

9. Supporting enforcement actions.

10. Documenting episodes and initiating episode controls. L14-10

11. Documenting population exposure and health research.

12. Providing information to:
    (a) public - air pollution indices; and
    (b) city/regional planners, air quality policy/decision makers - for activities related to programs such as air quality maintenance planning (AQMP), prevention of significant deterioration (PSD) and the preparation of environmental impact statements.

These are rather broad but should start the process, now on to "Locating general - level Regional Scale Stations" for SO_2 measurements.

SO_2 monitoring sites may be either: L14-11

Proximate - oriented toward measuring concentrations resulting from specific source or group of sources.

General - Measurement of total concentrations where contributions from individual sources are either not required to be known or do not predominate.

Other concept in title is of spatial scale. Concept is applicable to all pollutants. Is useful in describing and defining sites.

Spatial Distances are approximate (±10%). Scales are as follows:

Microscale. Ambient air volumes with dimensions ranging from meters up to about 100 meters are associated with this scale. L14-12

Middle Scale. This scale represents dimensions of the order from about 100 meters to 0.5 kilometers and characterizes areas up to several city blocks in size. L14-13

Neighborhood Scale. Neighborhood-scale measurements would characterize conditions over areas with dimensions in the 0.5 to 4.0 kilometer range. L14-14

Urban Scale. Urban-scale measurements would be made to represent conditions over areas with dimensions on the order of 4 to 50 kilometers. L14-15

Regional Scale. Conditions over areas with dimensions of as much as hundreds of kilometers would be represented by regional-scale measurements. These measurements would be applicable mainly to large homogeneous areas, particularly those which are sparsely populated. L14-16

National and Global Scales. These measurement scales represent concentrations characterizing the nation and the globe as a whole. L14-17

For this example, we are using regional scale.

So 1st, determine purpose of site L14-18

either A. Assess SO_2 transport L14-19

or B. Determine Regional Mean concentration L14-20

II. Assemble Site Selection Aids - (Addresses for providers of aids in back of SO_2 siting manual-Appendix A & D) L14-21

1. Climatological Data
   - (a) Assess representativeness for site or area L14-22
   - (b) Choose season for stability and wind rose data if possible
     - (1) Winter versus summer
       Peak energy demand tied to maximum
       SO_2 production
     - (2) Different Meteorological Features
       prevailing winds
       frequency of inversions
       heights of inversions

2. Maps L14-23
   - (a) U.S. Geological Survey
   - (b) Sanborn
   - (c) Aerial
   - (d) Satellite

3. Population Data L14-24
   - (a) Census Bureau
   - (b) Local planners

4. Diffusion Model Output L14-25
   Optional, yet desirable (See Appendix E of SO_2 Manual)

STEP 3 OF PROCESS

III. Defining general siting area

Work with left side of flow chart first. L14-26

Assess SO_2 transport L14-27
Interstate - Urban area
Interstate - General
Intercity

Interstate-Urban Area - defines state line and two areas of interest L14-28

CONTENT OUTLINE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Course: 435 - Lesson #14
Lecture Title: SITE SELECTION

Page 5 *of* 6

NOTES

Since looking at transport into state, don't want emission from own city interfering - so eliminate sites within interference distance either by removing source (attempt at humor) or modeling. L14-29

Slide indicates humorous approach to removing source

Interference distances are determined by modeling worst case conditions using a Gaussian model. They differ depending on the scale. For regional scale, they are:

Eliminate Prospective Specific Sites Within: L14-30

- 30 km of large point sources, e.g., 400 MW power plant.
- 15 km of medium-sized town, population 25,000
- 10 km of large industrial source, emissions 500 T/yr.
- 0.6 km of individual home (10^3 gal/yr of #2 oil).

Now add appropriate interference distance and wind rose. Wind rose is a statistical representation of wind data. Most commonly, the longer the bar off of the circle, the more frequently winds blow from that direction L14-31 L14-32

1. Primary Site
   Site is as close as possible to state line if looking for maximum impact-not most frequent impact. Ask students to locate L14-33
2. Secondary Site
   Downwind, just across state line L14-34
3. Additional Sites
   If blessed with many monitors, ideally would cover all of state line (as with SO_2 bubblers perhaps) L14-35

Interstate-General L14-36
Similar reasoning, along state line. Note interference distance and winter wind rose. (Winter, if applicable)

Intercity

1. Define area L14-37
2. Interference distance + wind rose L14-38
3. Primary site - located in area from prevailing wind direction L14-39
4. Secondary site - 2nd prevailing wind direction L14-40

Before discussing individual site characteristics or probe location, finish right side of flowchart.

Regional Mean Concentration L14-41

1. Define area - mixture of sources
2. Add appropriate interference distances L14-42
3. Appropriate wind rose L14-43
4. Diffusion Model Output L14-44
   ensure your concentration gradient is not too steep
5. Locate site - upper left of figure (see figure 4-3, p. 34 of SO_2 siting manual)

STEP 4 OF SITING PROCESS

L14-45

IV. Establish final site(s)

Having located areas of possible siting, a few final considerations

1. stationary or mobile L14-46
2. availability L14-47
3. security L14-48
4. cost L14-49
5. topography L14-50
   avoid low lying areas L14-51
   uniform topography - all flat or all hills, etc. L14-52
6. probe location - different for each pollutant L14-53
   but generally between 3-15 m. above ground. Probe constructed of non-reactive material.
7. Others L14-54

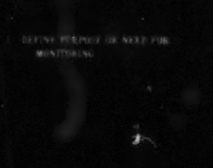
Summarize and emphasize that these are the simplest examples from the SO_2 Manual, and that the siting documents are useful. This example was covered to illustrate the approach to give an idea of what to expect, Manual covers many other more complex siting problems.

This siting approach is not necessarily "the" siting approach, yet it has several good points:

1. It is the EPA approach
2. It is a logical, systematic approach that allows a logical selection of a monitoring site and provides for suitably documenting your choice.

11/79 435 LESSON 14 21

1


1. DEFINE PURPOSE OR NEED FOR MONITORING

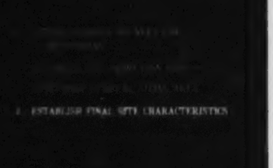
2

2. ASSEMBLE SITE SELECTION AIDS

3

3. DETERMINE GENERAL SITING AREA

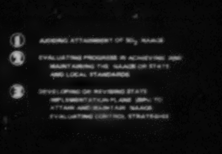
4


4. ESTABLISH FINAL SITE CHARACTERISTICS

5

DEFINE PURPOSE OR NEED FOR MONITORING

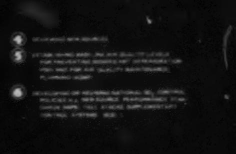
6


① AIDING ATTAINMENT OF SO_2 NAAQS

② EVALUATING PROGRESS IN ACHIEVING AND MAINTAINING THE NAAQS OR STATE AND LOCAL STANDARDS

③ DEVELOPING OR REVISING STATE IMPLEMENTATION PLANS (SIPs) TO ATTAIN AND MAINTAIN NAAQS, EVALUATING CONTROL STRATEGIES

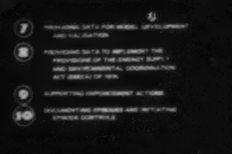
7


④ REVIEWING NEW SOURCES

⑤ ESTABLISHING BASELINE AIR QUALITY LEVELS FOR PREVENTING SIGNIFICANT DETERIORATION (PSD) AND FOR AIR QUALITY MAINTENANCE PLANNING (AQMP)

⑥ DEVELOPING OR REVISING NATIONAL SO_2 CONTROL POLICIES

8

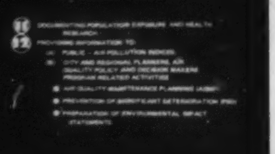

⑦ PROVIDING DATA FOR MODEL DEVELOPMENT AND VALIDATION

⑧ PROVIDING DATA TO IMPLEMENT THE PROVISIONS OF THE ENERGY SUPPLY AND ENVIRONMENTAL COORDINATION ACT (ESECA) OF 1974

⑨ SUPPORTING ENFORCEMENT ACTIONS

⑩ DOCUMENTING EPISODES AND INITIATING EPISODE CONTROLS

9


⑪ DOCUMENTING POPULATION EXPOSURE AND HEALTH RESEARCH

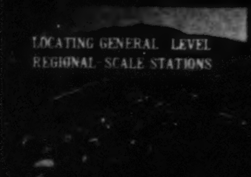
⑫ PROVIDING INFORMATION TO:

(a) PUBLIC - AIR POLLUTION INDICES

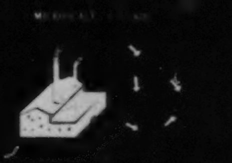
(b) CITY AND REGIONAL PLANNERS, AIR QUALITY POLICY AND DECISION MAKERS, PROGRAM RELATED ACTIVITIES

- AIR QUALITY MAINTENANCE PLANNING (AQMP)
- PREVENTION OF SIGNIFICANT DETERIORATION (PSD)
- PREPARATION OF ENVIRONMENTAL IMPACT STATEMENTS

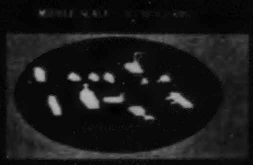
10


LOCATING GENERAL LEVEL REGIONAL SCALE STATIONS

11


MICROSCALE

12


MIDDLE SCALE

13

14

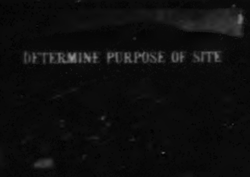
15

URBAN SCALE
4 to 50 km
>50 km

16

NATIONAL AND GLOBAL SCALES

17


DETERMINE PURPOSE OF SITE

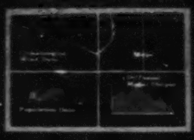
18

ASSESS SO_2 TRANSPORT

19

REGIONAL MEAN CONCENTRATION

20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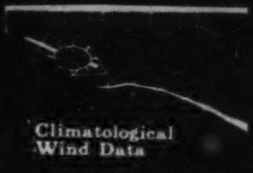
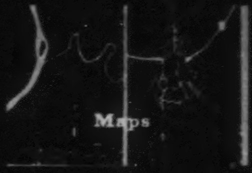

Climatological
Wind Data

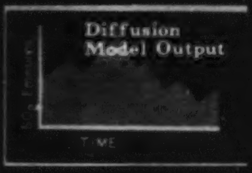
22



23

Population Data

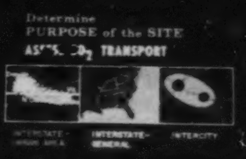
24



25

GENERAL SITING AREA

26


Determine PURPOSE of the SITE

ASSESS SO_2 TRANSPORT

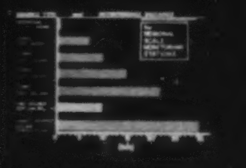
INTERSTATE - URBAN AREA
INTERSTATE - GENERAL
INTERCITY

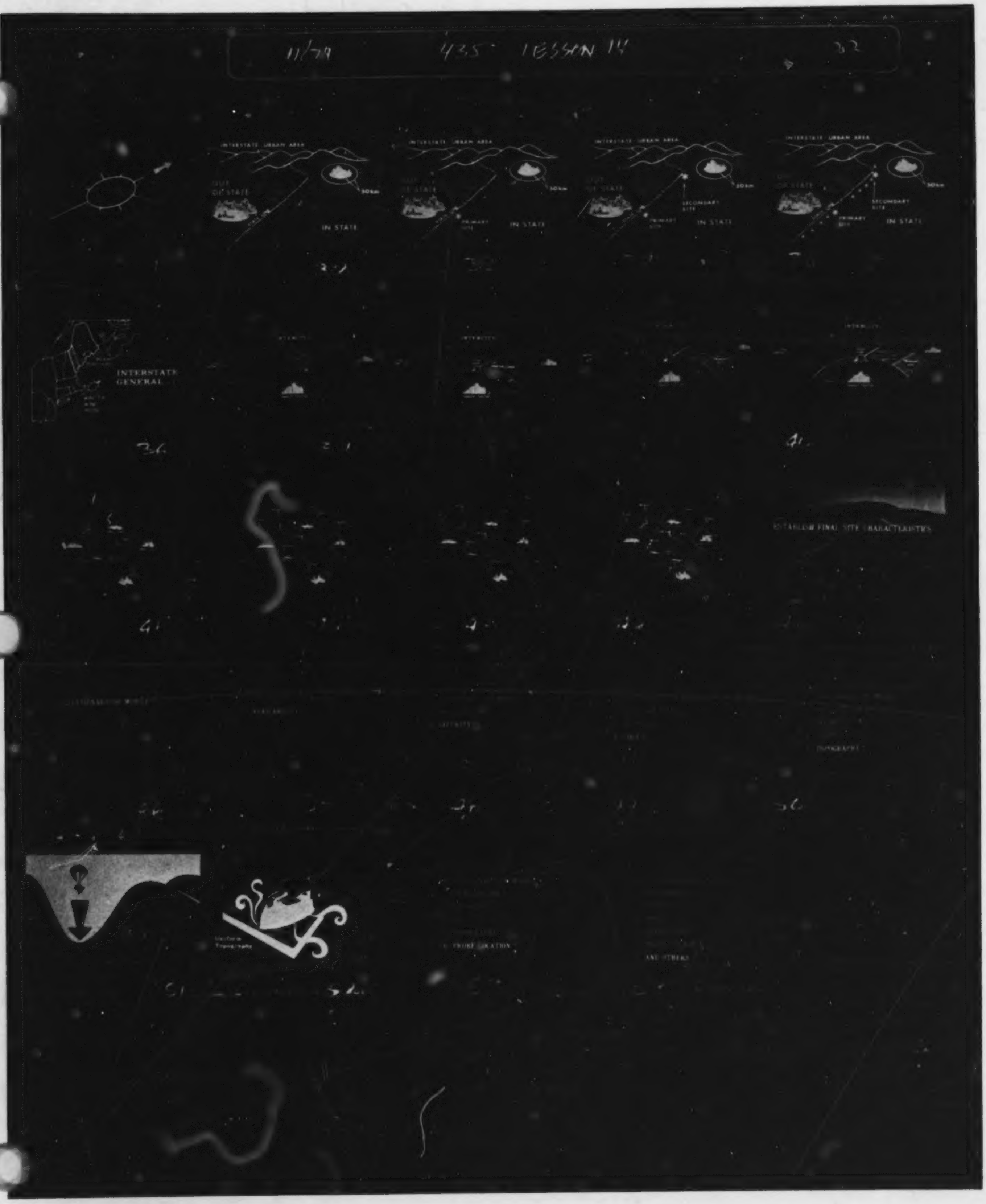
27

INTERSTATE - URBAN AREA
OUT OF STATE
IN STATE

28

29


30


11/79 435 LESSON 14 32

INTERSTATE URBAN AREA
OUT OF STATE
30km
IN STATE
PRIMARY SITE
SECONDARY SITE
INTERSTATE GENERAL
ESTABLISH FINAL SITE CHARACTERISTICS
TOPOGRAPHY
Uniform Topography
AND OTHERS
36
41
41
56
51

LESSON PLAN

AIR POLLUTION TRAINING INSTITUTE

TOPIC: ASSURING HIGH QUALITY DATA

COURSE: 435 - Lesson #15
LESSON TIME: 30 Min.
PREPARED BY: Northrop Services, Inc.
DATE: 2/15/79

LESSON GOAL: Identify general characteristics of Quality Assurance as they apply to atmospheric sampling and analysis and develop an appreciation for Quality Assurance.

LESSON OBJECTIVES:

The student should be able to :

1. Define Quality Assurance.
2. State three major reasons why a quality assurance program is important in sampling and analyzing atmospheric pollutants.
3. Recognize that many different quality assurance elements are involved in the process of producing valid data, list several of those which are directly applicable to the individual who samples and analyzes atmospheric pollutants.
4. Recognize that QA principles and specified QA methodologies are located in Vols. I & II of the Quality Assurance Handbook and 40CFR58 Appendixes A and B.
5. Recall that EPA conducts an Interlaboratory Performance Audit Survey and that participation (voluntary at present) will be required by 1983 in accordance with SLAMS provisions.

SUPPORT MATERIALS AND EQUIPMENT:

35 mm slide projector - required

Overhead projector or blackboard not required, but convenient to have available.

15

SPECIAL INSTRUCTIONS: This lecture should be covered quickly with emphasis on the sources of information for quality assurance. Try to get students to see the need for quality assurance.

SELECTED REFERENCES:

Quality Assurance Handbook, Vol. I, EPA-600/9-76-005
Vol II, EPA-600/4-77-072a
Published by EPA, Quality Assurance Branch, MD-77, Research Triangle Park, N.C. 27711

AIR POLLUTION TRAINING INSTITUTE

CONTENT OUTLINE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Page 1 of 4

NOTES

Course: 435 - Lesson #15
Lecture Title: ASSURING HIGH QUALITY DATA

I. INTRODUCTION

A. Objectives

Refer students to objectives handout read objectives to students

B. Quality Control vs. Quality Assurance

Quality Control - system of activities to provide you with a quality product.

Quality Assurance - system of activities that assures that the quality control system is performing adequately.

L15-1

Quality Assurance can be called "quality control on quality control."

II. QUALITY ASSURANCE

Class Question: What is the principal product of an air pollution measurement system? DATA

L15-2
L15-3

Class Question: What is the principal product of a QA program? valid data.

L15-4
L15-5

No data is better than incorrect data

Class Question: Why is a quality assurance program important?

L15-6

It is cost effective: in the long run, the cost per bit of valid data is less expensive.

L15-7

Minimize bad data

It adds credibility to data

It supports legal cases: Data supported by quality assurance is virtually unassailable in a court of law. Environmental lawyers have learned how to attack data validity, and validation of data thru a QA program is very difficult to discredit.

III. QUALITY ASSURANCE WHEEL

L15-8

Organization

Responsibility of several people (approximate percent responsibility)

CONTENT OUTLINE

Course: 435 - Lesson #15
Lecture Title: ASSURING HIGH QUALITY DATA

Page 2 of 4

NOTES

23 elements involved in QA Program

Consider only certain elements in this course
- data validation
- audit procedures
- preventive maintenance
- sample collection
- sample analysis
- data reporting
- calibration

IV. REFERENCES

Quality Assurance Handbook L15-9

Vol. I: Principles
Vol. II: Ambient Air Specific Methods
Vol. III. Source Emissions Specific Methods

Available free-of-charge from L15-10

Environmental Monitoring Systems Laboratory
MD-77
Environmental Protection Agency
Research Triangle Park, N.C. 27711

(Also should mention 40CFR58 Appendixes A and B (May 9, 1979)

V. The Measurement Process

3 basic components

(1) Separation of pollutant from the air matrix in which it is mixed. L15-11

Physical or chemical separation

ex. SO_2 - collect in TCM

ex. CO - instrumental method only "sees" CO, so it is "separated" from the rest of the air matrix

(2) Determine pollutant quantity and air matrix volume

(3) Calculate concentration by dividing pollutant quantity by air volume.

Calibration is the process of establishing the relationship between the output of a measurement process, or portion thereof, and a known input. L15-12

THE SINGLE, MOST IMPORTANT STEP IN THE MEASUREMENT PROCESS IS CALIBRATION.

AIR POLLUTION TRAINING INSTITUTE

CONTENT OUTLINE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

NOTES

Course: 435 - Lesson #15
Lecture Title: ASSURING HIGH QUALITY DATA

Six Elements of a Calibration Program L15-13a

(1) Statements of allowable time between calibrations usually maximum time allowable

(2) Statements of minimum quality of calibration standards L15-13b
ex. Chemicals - ACS reagent grade (minimum)

(3) Statements of proper environmental conditions L15-13c
ex. Hi Vol filters - equilibrated at 50% RH

SO_2 samples stored prior to analysis at less than $5^{\circ}C$. Electrical power: controlled? regulators needed?

(4) Provisions for written procedures L15-13d
Make calibrations, analyses, etc. less operator dependent

(5) Provisions for standards traceability L15-13e
all calibration standards should be traceable to standards of higher accuracy NBS-SRM's preferred.

(6) Provisions for proper record-keeping L15-13f
station log books
laboratory note-books
"chain of custody"

VI. THE AUDIT PROCESS L15-14

Intralaboratory audits
"within your own laboratory"

Interlaboratory audits
"between laboratories"

collaborative testing

EPA Performance Audit Program (describe program)

Semi-annual audit program
Free to participants
Schedules published in: L15-15
JAPCA
Quality Assurance Newsletter
Stack Sampling News

To find out more about program, contact:

Your Regional Quality Assurance Coordinator

L15-16

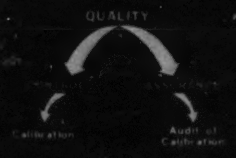
OR

Write: Director, EMSL
US EPA, MD-77
Quality Assurance Division
Research Triangle Park, NC 27711

Students who are interested in a more in-depth coverage of Quality Assurance as it deals with air monitoring are recommended to take APTI course. . .

#470 Quality Assurance for Air Pollution Measurement Systems

11/79 435 LESSON 15 23



QUESTION...

What is the principal product of an air pollution measurement system?

2

...ANSWER

DATA

3

QUESTION...

What is the principal product of a Quality Assurance Program?

4

...ANSWER

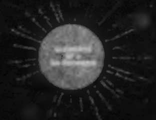
VALID DATA

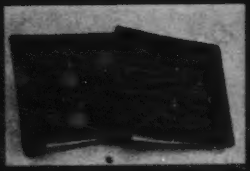
QUESTION...

Why is a Quality Assurance Program important?

...ANSWER

- Cost effectiveness
- Data credibility
- Legal support





9

WRITE TO:

ENVIRONMENTAL MONITORING
SYSTEMS LABORATORY
Quality Assurance Division
US EPA, MD 77
Research Triangle Park, NC 27711

10

AIR POLLUTION MEASUREMENT

- Separate pollutant from air
- Determine pollutant quantity and air volume
- Calculate pollution concentration by dividing pollutant quantity by air volume

11

CALIBRATION — the process of establishing the relationship between the output of a measurement process and a known input

12

ELEMENTS OF A CALIBRATION PROGRAM

- Statements of ALLOWABLE TIME between calibrations

13a

ELEMENTS OF A CALIBRATION PROGRAM

- Statements of ALLOWABLE TIME between calibrations
- Statements of MINIMUM QUALITY OF CALIBRATION STANDARDS

13b

ELEMENTS OF A CALIBRATION PROGRAM

- Statements of ALLOWABLE TIME between calibrations
- Statements of MINIMUM QUALITY OF CALIBRATION STANDARDS
- Statements of proper ENVIRONMENTAL CONDITIONS

ELEMENTS OF A CALIBRATION PROGRAM

- Statements of ALLOWABLE TIME between calibrations
- Statements of MINIMUM QUALITY OF CALIBRATION STANDARDS
- Statements of proper ENVIRONMENTAL CONDITIONS
- Provisions for WRITTEN PROCEDURES

13d

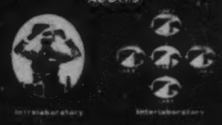
ELEMENTS OF A CALIBRATION PROGRAM

- Statements of ALLOWABLE TIME between calibrations
- Statements of MINIMUM QUALITY OF CALIBRATION STANDARDS
- Statements of proper ENVIRONMENTAL CONDITIONS
- Provisions for WRITTEN PROCEDURES
- Provisions for STANDARDS TRACEABILITY

ELEMENTS OF A CALIBRATION PROGRAM

- Statements of ALLOWABLE TIME between calibrations
- Statements of MINIMUM QUALITY OF CALIBRATION STANDARDS
- Statements of proper ENVIRONMENTAL CONDITIONS
- Provisions for WRITTEN PROCEDURES
- Provisions for STANDARDS TRACEABILITY
- Provisions for proper RECORD KEEPING

AUDITS



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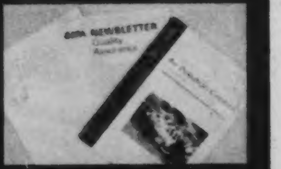

WRITE TO:

ENVIRONMENTAL MONITORING
SYSTEMS LABORATORY
Quality Assurance Division
US EPA, MD 77
Research Triangle Park, NC 27711

COURSE 435 - ATMOSPHERIC SAMPLING

LABORATORY INSTRUCTIONS

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I. Lab Facilities — should ideally have 3 separate rooms (can go with 2 rooms or one large room)

— total of 10 people in each lab at one time

Lab 1: Hi Vol Lab
25 feet of standard lab bench top space
2 to 4 electrical outlets
extremely noisy lab — ideally should have its own room.

Lab 2: Flow Lab
30 feet of standard lab bench top space 4 to 6 electrical outlets
tap water supply is nice.

Lab 3: Test Atm.
25 feet of standard lab bench top space
6 to 8 electrical outlets
Lab exhaust hood is best (can possibly do without)

Total of 80 feet of standard lab bench top space.

II. Laboratory Materials and Equipment

The following list indicates the equipment and materials required for successful presentations of the lab sessions using the procedures contained in the Course 435 Laboratory Manual.

Equipment List - Lab #435 Atmospheric Sampling

(A) LAB 1 - CALIBRATION OF A HIGH VOLUME SAMPLER

1. Portable "in the field" calibration kit (optional)
2. 2 - Pressure transducers (Dixon meters) and Hi-vol blowers.
3. 2 - Visifloat and Hi-vol blowers (used with rootsmeters)
4. 4 - Rootsmeters with stands
5. 4 - Water manometers - capable of measuring 16 inches or more.
6. 2 - Mercury manometers - capable of measuring 160 mm or more.
7. 4 - Ring stands and 10 - 3 prong holder clamps
8. 2 - Sierra or other make constant flow controller units
9. (and calibrator to correspond to constant flow unit)
10. One cartridge "type" filter holder (optional)
11. 2 - Orifice units (calibrator with load plates)
12. 4 - Electrical outlet - multiplugs - (extension cords okay)
13. 2 - Reference flow devices (Ref) (Dexco, Inc.)
14. Tubing - thin walled - Tygon
15. Miscellaneous - (A) rubber gaskets
    (B) one box of clean filters (glass fiber)
    (C) oil - (rootsmeter grade oil)
    (D) Mercury
    (E) Distilled water with added coloring - ten drops/liter H_2O e.g. fluorescein green dye

(B) LAB 2 - FLOW MEASURING INSTRUMENTATION

1. 2 - Mass flowmeters (0-3 liter range)
2. 2 - Displacement bottles (10 liter capacity)
3. 2 - Two liter class "A" volumetric flasks
4. 2 - Wet test meters (1 liter/rev)
5. 2 - Stopwatches
6. 2 - vacuum pumps (capable of pulling 25" Hg vacuum)
7. 4 - Smog bubblers
8. 8 - Gas metering valves
9. 6 - Vacuum gauges (0-30 "Hg vacuum range)
10. 4 - 500 ml Erlenmeyer flasks (plastic)
11. 2 - Particulate filters and holders (Teflon filters)
12. 2 - Moving soap bubble meters (graduated 0-500 ml)
13. 500 ml soapbubble solution
14. 2 - 250 ml beakers
15. 10- Metal squeeze clamps for glass sockets
16. 4 - One-holed stoppers (rubber)
17. 2 - 2-holed stoppers (rubber)
18. 2 - 500 ml washbottles
19. 10 - ring stands
20. 4 - Mounting rods (horizontal)
21. 28 - 3-prong clamps
22. 2 - rotameters (glass) (0-3ℓ range)
23. 2 - 23 gauge hypodermic needles
24. 36 - clamp holders with 45° angle thumbscrews
25. 40' - 50' of vacuum tubing (rubber)
26. 6' - thin walled tubing (rubber)

(C) LAB 3 - STANDARD TEST ATMOSPHERES EQUIPMENT REQUIRED*

1. Continuous SO_2 Analyzer - (e.g. Teco Model 43)
2. Continuous NO_x - NO_2 - NO Analyzer (e.g. Bendix 8102)
3. Portable Dilution system (e.g. Bendix Model 8861D)
4. Portable permeation system (e.g. Bendix Model)
5. Misc.
    - (a) hardware Swagelok fittings - clamps
    - (b) tubing (e.g. Teflon and/or glass)
    - (c) mixing bulbs - (glass) and/or glass manifold
    - (d) support gases needed
        - (1) zero air
        - (2) NO bottled gas (50 ppm)
    - (e) permeation tube 1 μg/min SO_2 @ calibrator/permeation oven temperature

*May substitute other equipment so long as the principles put forth in the lab write-up are demonstrated i.e., permeation/dilution system utilized to calibrate monitor and gases and their dilution as an alternate calibration method.

III. SPECIAL INSTRUCTIONS

Lab 1: Hi Vol Lab

a. Divide groups in half during their first lab session. They will remain in these groups throughout the 3 labs.

b. Each group of about four will first calibrate an orifice vs. a rootsmeter. Go over with them first the proper principle/operation of a rootmeter.

- Show them oil level indications - 3 of them.
- Explain why the mercury manometer is used and give a demonstration of the pressure drop.
- Show the volume indicator and explain why we use the non-compensated dial — because gas companies usually utilize the meter and they use 60°F as their standard temperature.
- Explain how to read a mercury vs. a water manometer.
- Mercury the top of the meniscus vs. the bottom for a water manometer. - due to the properties of these two liquids.
- If there is a mercury barometer available explain how to read it. Take a temperature reading as well, ideally the temperature should be the temperature in the room.
- Rootsmeters should be warmed up prior to calibration procedures. See Lab Manual.

c. After the orifice unit is calibrated vs. a rootsmeter have the groups now calibrate a visifloat and/or a transducer (ideally both) vs. the orifice. Explain how to read a rotameter - center of ball and and how to set up and read a pressure transducer. (Should zero them first - and remember to tap them before you take a reading). See instruction manual.

d. Next exercise consists of checking the orifice curve with a ReF flow audit device. Follow instructions and explain to students why this unit is more accurate. (1) more highly precisioned (i.e. plates) (2) placed on top of the sampler head vs. screwed on top of blower motor. Remember to perform a leak check with the plate without any hole. (This might be a plate with one hole and should be closed with enclosed screw and wing nut). K values are given with each unit. (received from EPA).

e. Last exercise consists of checking the constant flow control unit. Follow directions and explain to students how flow is critical in the method as well as going over the principle of operation, i.e., flow sensing anemometer.

f. Explain all calculations that are to be used in this lab.

Lab 2: Flow Lab

(a) Groups should be in their respective subgroups.

(b) Set-up as diagramed in lab exercise manual.

(c) Best to use two complete set-ups of each exercise on adjoining benches. This allows one group to start from one end of one bench and the other group the opposite end of the adjoining bench. (facilitates space allocation).

(d) Be sure the students have read over the instructions.

(e) Describe the procedural steps utilizing the set-ups themselves.

(f) Go over the lab data reporting requirements with each group. (i.e., which data sheets should be turned in for grading)

(g) Demonstrate proper reading of lab barometer (mercury barometer)

(h) While the lab is proceeding, go over with them the principles of operation/theory of a mass flow meter , wet-test meter, rotameter, moving bubble meters, and a limiting orifice.

(i) After data is collected, the students may re-enter the classroom to perform calculations and construct appropriate curves.

(j) Instructor should be present to assist with the calculations.

Lab 3: Test Atmospheres

(a) Instructor should thoroughly review operating manuals for the ambient air monitors and permeation systems used.

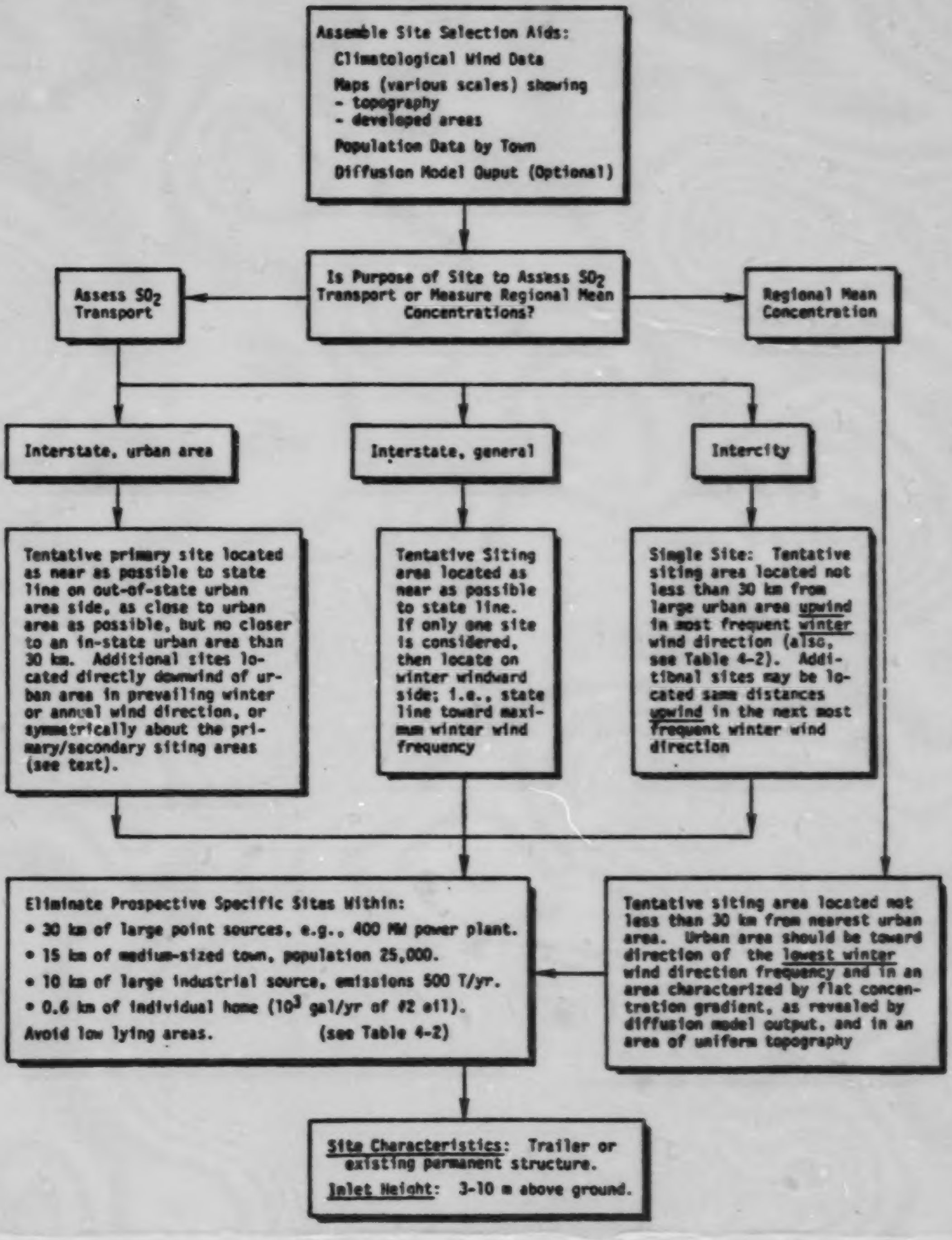
(b) Instruments should be check-out and running 48 hours before lab commences.

(c) Plumbing considerations include use of only Teflon/and or glass for pollutant gases. This should include both lines and fittings.

(d) Be sure students have read over instructions prior to lab. After this, instructor can demonstrate with the instruments the procedures themselves.

(e) See Lab 2 (f)(i)(j)

(f) While the lab is proceeding the students could benefit by added instruction concerning these items: principle/operation of instruments, handling of specialty gases and cylinders, permeation device operation and calculations involved.


Assemble Site Selection Aids:
Climatological Wind Data
Maps (various scales) showing
- topography
- developed areas
Population Data by Town
Diffusion Model Ouput (Optional)
Is Purpose of Site to Assess SO_2 Transport or Measure Regional Mean Concentrations?
Assess SO_2 Transport
Regional Mean Concentration
Interstate, urban area
Interstate, general
Intercity
Tentative primary site located as near as possible to state line on out-of-state urban area side, as close to urban area as possible, but no closer to an in-state urban area than 30 km. Additional sites located directly downwind of urban area in prevailing winter or annual wind direction, or symmetrically about the primary/secondary siting areas (see text).
Tentative Siting area located as near as possible to state line. If only one site is considered, then locate on winter windward side; i.e., state line toward maximum winter wind frequency
Single Site: Tentative siting area located not less than 30 km from large urban area upwind in most frequent winter wind direction (also, see Table 4-2). Additional sites may be located same distances upwind in the next most frequent winter wind direction
Eliminate Prospective Specific Sites Within:
• 30 km of large point sources, e.g., 400 MW power plant.
• 15 km of medium-sized town, population 25,000.
• 10 km of large industrial source, emissions 500 T/yr.
• 0.6 km of individual home (10^3 gal/yr of #2 oil).
Avoid low lying areas. (see Table 4-2)
Tentative siting area located not less than 30 km from nearest urban area. Urban area should be toward direction of the lowest winter wind direction frequency and in an area characterized by flat concentration gradient, as revealed by diffusion model output, and in an area of uniform topography
Site Characteristics: Trailer or existing permanent structure.
Inlet Height: 3-10 m above ground.

. Flow chart showing procedures for locating general-level regional-scale stations.

Siting Handout